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FLOW OF METALS IN THE DRAWING-PROCESS.

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[*A Lecture delivered before the* FRANKLIN INSTITUTE, *January 29, 1886.*]

LADIES AND GENTLEMEN:—In introducing the subject upon which I have been asked to address you this evening, "The Flow of Sheet-Metals in the Drawing-Process," I will refer briefly to *flowing*, in general, and to this motion as it occurs in various metallic and other solid materials. Webster defines "flowing" as moving "with a continual change of place among the particles or parts, etc., as in a liquid," and to many people the idea is connected only with liquids and other fluids. A further flow of the brain molecules which are supposed to represent their inner consciousness, however, will soon show them that such motion is a very common phenomenon in all the events transpiring in daily life before their eyes, both in semi-fluids and in solids; also, that this flow may be *elastic* or *non-elastic*.

Common instances of elastic flow may be found in the wonderful stretching of a piece of india-rubber to perhaps ten times its normal length, and its indignant return to exactly its original form;

or in the bending or twisting of any wooden or metallic springs, etc., etc.

Instances of non-elastic flow are observed most frequently perhaps in connection with semi-solids, such as the clay upon the potter's wheel, the dough in the hands of the house-wife, or the putty under the glazier's knife. In the apparently rigid solids, such action is not popularly conceivable, but a little observation will show that the cold-forging of a piece of iron, or, indeed, any bending or other permanent distortion of any piece of metal, could not occur without this flowing of its molecules among themselves. Such flowing is shown on the grandest scale known to our present experience (whatever may have happened in the mighty work-shops of geological science) in the glaciers of the Alps, where great masses of solid ice flow slowly down their confining channels, changing their shape of cross-section as needs be, without being crushed or suffering any disintegration of their substance. This has been well described by Professor Tyndall, and it is, if I remember rightly, the same distinguished prowler about Nature's portals who tried the very interesting experiments regarding the flow of foreign objects through solid pitch, without leaving any holes in it. I could not find the description of this experiment, the other day, in any books that I had at hand, but I believe it was as follows: A number of stones were placed upon the top of, and a number of corks underneath, a mass of pitch several inches thick, and abandoned to their fate. After several months of silent disappearance, the corks arrived at the top and the stones at the bottom of the pitch, having floated and sunk respectively to their natural destinations.

In looking for the flow of solids in the metallic arts, it will be well to omit all *hot* processes as dealing with semi-fluids; but familiar examples of cold flow may be seen in wire-drawing, tube-drawing, cold-rolling and hammering, lead-pipe making, sheet metal-spinning, etc.

The first two mentioned are obviously analogous, about the only difference being that the tube is hollow (usually with a mandrel inside of it), while the wire is solid. Very similar to these operations, as respects the direction of flow of the particles of metal, is the reducing of a rod in grooved rolls, the chief difference being that the metal is coaxed along by friction, so to speak,

instead of being pulled by its finished end. In hammering a bar, the tensile stresses are entirely omitted and the action is wholly compressive, in a lateral direction, of course.

In lead-pipe making we have also an entirely compressive action, but one very different from that in the last-named process. Here the lead is *squirted* out, as it were, much after the manner of a syringe, or a sausage-stuffer, or one of those curious, but really excellent, squirting brick machines, the only thing about which I could not understand being that it should figure (if I remember aright) as a *mechanical* novelty at the "Centennial," and an *electrical* novelty at a certain well-known exposition of later date.

In the spinning process, there is a great variety in the method of flow, as the shapes produced from a flat disc (though sometimes from a tube or cup) are of many kinds, and the metal is, by the action of the burnisher, stretched in some places and forced into a smaller diameter in others. This process, by the way, is a tedious and expensive one, and requires a treatise to properly describe it in all its variations. Happily, it is much less practised than formerly, and is for many purposes being superseded by the very much quicker, cheaper and more uniform drawing-process and its modifications. Spinning is, however, often useful as a supplementary operation in finishing some shape which cannot be made in the dies. Part way in principle, between tube-drawing and the process referred to in our title, is such work as cartridge-drawing, where a "cup," made in a drawing press proper, is afterwards "broached" at several subsequent successive operations by being pushed through a female die that is a little too small for it. This is, in effect, the same as tube-drawing, the male-die, or "punch," acting as the mandrel. The only difference is that the tube is comparatively short, and has an *end* in it. The end is usually, in the case of cartridge shells, left thicker than the sides. This is not, however, necessarily the case, as the proportional thickness of the sides depends upon the space between the punch and die relatively to the original thickness of the sheet-metal.

Coming nearer to the process which forms our subject proper to-night, we find that its immediate predecessor as a cheap substitute for spinning was the "stamping process." I have no correct data regarding its history, but its practice does not to much extent reach back into the last century. Its object was chiefly the

production of seamless utensils from tin-plate, sheet-iron, brass, zinc, etc. These comprised such articles, as pie- and jelly-plates, milk-pans, dish-pans, dippers, cups, shallow sauce-pans, wash-bowls, colanders, wash-boiler bottoms and other articles of approximately conical and hemispherical forms. A general idea of such work in its finished state is given by the pictures, which Mr. Hiltebrand will now kindly throw upon the screen. As will be seen,

FIG. 1.

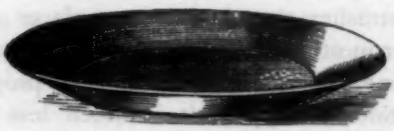


FIG. 2.

FIG 3.

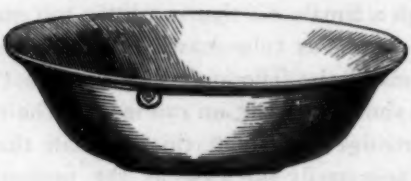


FIG. 4.

Fig. 1 is a bake-pan, *2* a pie-plate, *3* a milk-pan, and *4* a wash-basin. *Fig. 5* is a tea-kettle, in which there are three drawn pieces, namely, the cover and the upper and lower sections of the body. *Fig. 6* is a dish-pan. *Fig. 7* is an oil-can, in which the spout and bottom are, of course, separate pieces. *Fig. 8* is a ladle, to which the handle is riveted afterwards. *Fig. 9* is the bottom or well of

an ordinary wash-boiler. *Fig. 10* shows a screw-nozzle and cap, such as is used upon fruit-jars, oil-cans and other utensils. These

FIG. 5.

FIG. 6.

FIG. 7.

FIG. 8.

FIG. 9.

have the screw-thread automatically spun upon them after being drawn. *Fig. 11* is a tin-cup, and *12* an oval bake-pan. *Figs. 13*,

14, *16* and *17* are not properly drawn work, as the wrinkles have not been taken out, but only thrown into symmetrical forms, to answer as ornamental corrugations. *Fig. 15* is a shallow-plate,

FIG. 10.

FIG. 11.

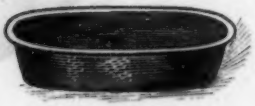


FIG. 12.

FIG. 13.

FIG. 16.

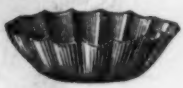


FIG. 17.

FIG. 14.

FIG. 18.

FIG. 15.

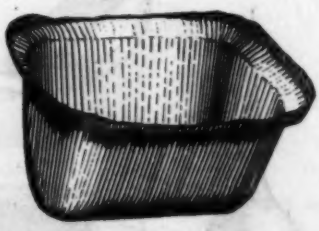


FIG. 20.

FIG. 19.

and *18* a dust-pan, to which, of course, the handle is attached afterwards. In *Fig. 19* is shown a rectangular box with rounded corners. In such work as this, the drawing-process proper applies only to the corners, and not to the straight sides, which obviously

have no flow of particles within them. These are simply bent up at right angles to the bottom, while in the corners, especially if of small curvature, the flow is very violent, making this one of the most difficult shapes to draw. In *Fig. 20* is shown a second operation, in which *Fig. 19* has been deepened and made smaller in diameter by a process, which will be explained further on. In

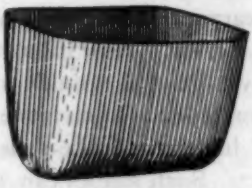


FIG. 21.

Fig. 21 is shown a third operation upon *Fig. 19*, where the flange has been turned up and trimmed. This turning up of the flange is not properly drawing, although the metal has to be upset, or crowded together. It is done by forcing the article down through a die, and can only be applied where the reduction in diameter is quite small, as otherwise the wrinkles would fold upon one another and the work be ruined. The article shown, as completed in *Fig. 21*, is intended for a seamless elevator bucket. In comparing *Figs. 13* to *17* with drawn work, and in describing the genesis of *Figs. 19* to *21*, I have digressed a little from "stamping" in order to explain these pictures while on the screen.

All the other work mentioned was usually done in a drop-press, although a crank-, lever- or screw-press could be employed, as far as the proper motion of the dies was concerned, had force enough been applied. The lower die was the female, or intaglio, and fitted the outside of the work before the wired or curled rim at the top was made; that is to say, the top of the die was a flat, smooth surface, extending some distance out, so that its outer diameter was fully as great as that of the blank. "Blank," it may be explained, is the technical name of the flat disc of sheet-metal which is to be formed to shape. The upper die was the cameo, technically the male-die, punch or "force," as in this process it was generally termed, and was usually made of an alloy of lead and tin which could be cast into the lower die while in the press, and thus a perfect fit be cheaply made. It had a flat flange, extending over

the flat top of the lower die, which served to mash the wrinkles out from the flange of the work—it being understood that the work is usually *hat*-shaped, with a flat projecting flange. This was afterwards wholly or partly trimmed off true, and was often curled over a wire ring, or else over the place where the wire ought to be—somewhat upon the principle of the Irishman's "empty bag with praties in it." This latter process is known as "false-wiring" or "curling." The appearance of either this or real "wiring" is shown at *Figs. 4, 11, 15*, etc. Now it is obvious that a flat disc formed into a concave die will wrinkle near its periphery on account of being there reduced in circumference. This principle is taken advantage of in making cake-pans and such work. See *Figs. 13, 14, 16* and *17*. Such shapes can easily be made perfect at one blow, because the corrugations are systemized wrinkles, of the proper amplitude to just take up the surplus metal. If the work must be smooth, the wrinkles can be mostly, but not wholly, mashed out by a heavy enough blow, *providing* the wrinkles are quite shallow, so that one cannot possibly fold over upon another. Of course, in so doing the metal must be "upset," or crowded together in a circumferential direction. In order that the wrinkles may be thus shallow, the work must be shallow relatively to its diameter, say as one to fifteen or twenty, in ordinary sizes of tinware, with a metal as thin as tin-plate, which averages perhaps only about one-sixty-fourth-inch thick. (It may be said, *en passant*, that with much thicker metals, *e. g.*, a piece of one-fourth-inch boiler plate made into a pie-dish, the metal is so braced within itself that it "upsets" to a great extent *before* the wrinkles form, and they are apt to be almost *nil.*) To make deep work by the stamping process, it became necessary to *coax* the metal down, so to speak, by several successive operations—sometimes as many as eight or ten. For these, the same "die" was used with several "forces," each one having its convex part projecting below its flat flange a little further than the last, say from one-half inch to one inch. This flange beat out the newly-formed "flange-wrinkles" at each operation, while the same thing was done for the "body wrinkles" (those in the conical surface) by the nearly touching sides of die and force. An incidental advantage about such soft-metal "forces" as we have been considering, besides their cheapness and facility for fitting, is their capacity for a ready internal

flow of their particles by the force of the press's blow, thus forging themselves to exact shape each time, in spite of their tendency to wear and mash out of shape. This is especially the case when they are used in a drop-press, where there is great force and rapidity of percussion at the extreme bottom of the stroke.

The *drawing-process* proper, which we are especially to consider to-night, and which will be more fully described further on, was designed as a substitute for stamping, and consists in confining the flange of the work between two parallel surfaces so tightly that wrinkles have *no room to form*, and its molecules consequently flow outward radially to compensate for what they must flow together circumferentially, as their diameter at any given place is reduced. Its products show deeper and better work in one operation than could be obtained in several successive ones by stamping. Curiously enough, the *name* of the last-mentioned process has been retained by many of the manufacturers who make nearly all their work by drawing, using only an occasional drop-press for auxiliary operations. It should be understood, then, that when we read in the newspapers of the "Great American Conglomerated Association for the Diffusion of Good Prices Among Stampers," or see the market quotations for "stamped ware," we must interpret the term in a commercial, and not in a technically mechanical, sense. It is now generally supposed to comprise all seamless sheet-metal household utensils, as deep as a pie-plate, or deeper. These are usually made of tin-plate (the best qualities of goods being retinned after being brought to shape) or else of sheet-iron or steel coated with tin or with some porcelain-like material, of which there are several excellent varieties in the market. This term "stamped" seems to have its chief individuality as in contradistinction to "pieced"-ware, which is soldered together in sections.

Of the *history* of the drawing-process I have not been able, in a somewhat casual search, to find any printed record, except an encyclopædic statement that it was first practised by a Mr. T. Griffiths, in 1841. Mr. Grosjean, of New York, who probably first used it in this country, and has been one of its largest users ever since, informs me that he thinks it was practised in France as much as fifty years ago, but cannot be sure of the date. I am indebted to my friend, Mr. F. G. Niedringhaus, of St. Louis, for some valuable information upon this subject. He tells me that the

"Prussian system" of metal-drawing was invented by the Strouvelle Brothers, at Saarlouis, Rhenish Prussia, and was practised by them there, and, later, at Ars, Alsace. From there skilled artisans introduced it into this country early in 1866, it being put into practical working shape by the Lalance & Grosjean Manufacturing Company, and a little later by the St. Louis Stamping Company. Soon after this, one Marchand, who had been employed by the first-named company, and had learned something of the process, made it prematurely public, and commenced to build presses adapted to its practice. These bore his name, and were for a time the only ones in the American market. As their maker has long been out of the business, and is, I believe, now dead, I do not feel that I am unduly advertising his wares by thus making him a factor in history. Since his time various improvements have been made in the details of the process, and in the strength and convenience of the presses used. Many of the minor improvements in the manipulation of the metal have been kept secret by their inventors, and are practised only in a few large factories.

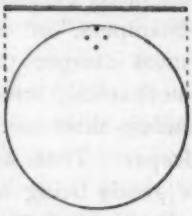


Fig. 23

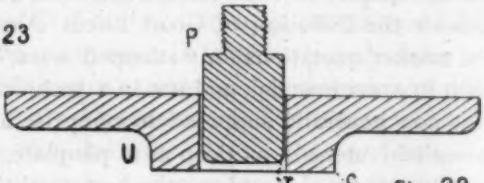
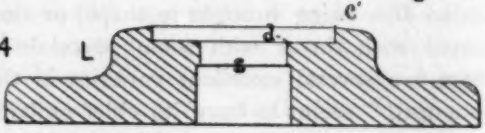


Fig. 22

Fig. 24



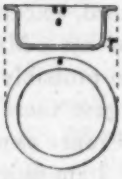


Fig. 25

Fig. 26

Proceeding to describe in detail the process in question, we see upon the screen in *Fig. 22*, a vertical section through the axis of a

pair of drawing-dies for plain cylindrical work, *L* being the lower die, *U* the upper die (sometimes termed blank-holder), and *P* the punch. Such a die may both cut and form the work at one stroke, *c* being the male cutting edge and *c'* the female cutting edge, or it may be used for blanks already cut, which are merely thrown into the recess formed by *c'*, it acting as a guide to hold them central. When the operations of cutting and forming are thus combined, it is usually termed a "combination drawing-die," and this type is very generally used for all small work, say up to twelve inches in diameter, while for larger work, it is often the practice to cut the blanks separately and make the dies of a cheap material, like cast-iron, which would not answer for cutting edges. There can now be purchased in the market, circles of tin-plate, which are tinned in that form, thereby saving the wastage which occurs from having the scrap-metal left at the corners of the rectangular sheet, uselessly coated with tin. Where, however, such circles are not used, the tendency is, I think, more and more towards the use of combination-dies, so as to do the whole work in as few operations as possible. Whichever way the blank may have been cut, the operation is as follows: The die *U* descends until the blank is firmly held between the two flat surfaces, when *U* remains stationary until the punch *P*, which has so far descended with it, continues its descent, drawing the metal into a cylindrical form, as shown in *Fig. 26*, and stripping it from the punch against the stripping-corner *s*, when the latter rises to its original position. The slight expansion of the top edge of the cup by the elasticity of the metal, is usually sufficient to prevent it from pulling up into the die again, although sometimes trouble is experienced unless the corner *s* is kept very sharp and hard. It is usually necessary to "vent" the punch by a small hole, running up through it, not shown in the drawing, in order that the suction of the air cannot help to pull the cup upward. The rising to a normal position of the upper-die may occur at any time after the flange of the work has disappeared around and below the corner *d*, but this rising usually takes place at the last part of the stroke and simultaneously with the last part of the upward motion of *P*.

In *Fig. 23* is shown a section and top view of the blank before being drawn. In *Fig. 24* is the same as it appears when it has been drawn to about one-third of its depth, and in *Fig. 25*, when

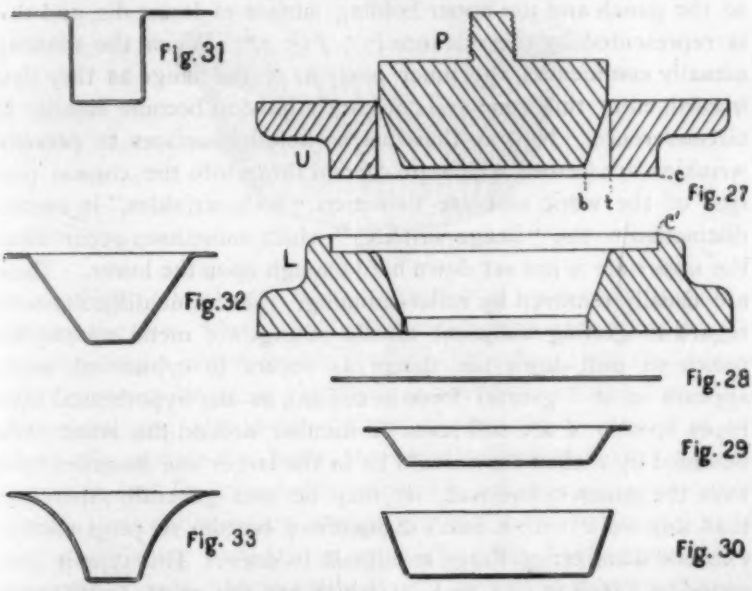
about two-thirds. In *Fig. 26* is shown the completed cup, the flange having entirely disappeared. The direction in which the metal is forced to flow, is shown graphically by the four dots in the form of a square upon *Fig. 23*. In the subsequent figures, these dots will be seen to have assumed the form of a diamond, whose axis, lying in a radial line, continuously lengthens, while its other axis, lying in a tangent, is to about the same extent shortened, thus showing that the metal is stretched radially with its particles flowing away from each other, while circumferentially it is upsetting, and the particles are approaching.

The question naturally occurring to the uninitiated is, what is the limit of depth to which an article can be drawn from a flat sheet of metal? This depends upon a variety of circumstances, such as the kind and quality of metal, its thickness relatively to the size of the work, etc. A good quality of "one-cross" (I-X) tinplate, which is about one-sixty-fourth-inch thick, can, in small articles, say under eight inches across, be drawn to a depth equal to about one-half of its diameter, although I have known frequent cases where this depth has reached two-thirds; for instance, a 3-inch box, 2 inches deep, etc. With soft brass and copper, a somewhat greater depth can be obtained, while with zinc, the proportional depth is considerably less. I have had but little experience in drawing gold and silver, but as far as I know, they act much in the same way as does brass.

A little study of the work which is being done in a die like this will show why a limit of depth is soon reached. The actual work consists, firstly, of molecular friction, or the causing to flow among themselves of the particles of metal in the flange before it turns the corner *d*; and secondly, in overcoming the friction between the upper and lower sides of the metal, and the flat surfaces of the dies. If we imagine the part of the work which has become cylindrical to be a series of little ropes (forming the elements of the cylinder), which are attached to the punch by running across under the bottom of it, and thence up its sides to the corner *d*, we will see that all the resistance offered in the flange is being overcome by the punch pulling these ropes downward over the corner *d*, it acting as a stationary pulley-block. Hence, if the united tensile strength of all these little ropes is great enough to overcome the resistance at its maximum, which is soon after the

metal begins to flow, when the flange is at its widest, perfect work will be the result. If, however, there are not enough ropes to do this work, which is the case when the diameter at *s* is too small, the flange will not start to move, but the punch will simply go down and tear the bottom out of the work. Thus, if we try for too great a depth relatively to the proposed diameter, the work will be spoiled, because this means a wide flange and more resistance.

It is evident that the little ropes spoken of will "render" more easily about a large corner than a small one, and that therefore a better result may be obtained by increasing the radius of the drawing-corner *d*. If, however, this is carried too far, a considerable part of the flat holding-surface of the lower die is lost, and a new



evil arises, known as body-wrinkles, which will be explained further on. Practically, for working tin-plate, the radius of the corner *d* is made from one-eighth to one-quarter inch. The curvature of the corner *r* upon the punch also affects the result. If it is made perfectly sharp, it tends to cut the metal which is pulled around it, and practically ought not to be less than of one-sixteenth inch radius. It is often much larger than this to suit shape

of work desired, but if made very large, causes the trouble of body-wrinkles before referred to, on account of there being a certain zone of the blank which is unconfined by the flat holding-surfaces.

You will now see upon the screen, a new diagram, marked *Fig. 27*. This is a vertical axial section of a pair of conical drawing-dies, similar to the last shown, except that they produce conical instead of cylindrical work. They, like the others, may either be "combination," or may work blanks already cut. In *Fig. 28* is shown a section of a blank and in *Figs. 29* and *30*, successive stages of the work while being drawn. The radical difference between this and cylindrical work consists in the blank being unconfined over a certain space which lies between the lower face of the punch and the upper holding surface of lower die, and this is represented by the distance *b*, *t*, *Fig. 27*. When the drawing actually commences, the inner portions of the flange as they flow inward, enter this zone and constantly have to become smaller in circumference. Now as there are no holding-surfaces to prevent, wrinkles are formed which are carried down into the conical portion of the work and are known as "body-wrinkles," in contradistinction to the "flange-wrinkles" which sometimes occur when the upper die is not set down hard enough upon the lower. These are usually removed by roller-spinning. The same difficulty with regard to getting sufficient tensile strength of metal around the punch to pull down the flange as occurs in cylindrical work, appears in still greater force in conical, as the hypothetical little ropes spoken of are still fewer in number around the small circle bounded by *b* than they would be in the larger one bounded by *t*, were the punch cylindrical. It may be said generally, therefore, that any work with a small diameter of bottom in proportion to extreme diameter of flange is difficult to draw. This type is illustrated in *Figs. 31*, *32*, and *33*, which are the most troublesome of all shapes to deal with.

I have before shown that the resistance to be overcome consists of both molecular and surface friction. In drawing conical articles, such as bowls, pans, etc., which do not require absolute uniformity and accuracy, advantage is taken of this fact by drawing two or more together, sometimes even as many as four. In such a case, the surface-friction is no greater for four than for one,

while the molecular friction is four times as great. The sum of these frictions is, however, obviously less in proportion to the tensile strength of work surrounding the punch, which is as the number of thicknesses therein. There is, therefore, a great gain in strength, and much deeper work may be made than by drawing one at a time.

These several thicknesses can also be removed from the press and spun and trimmed all at a time, after which they easily drop apart. This method is only applicable to work with considerable taper. Obviously, it would not answer with cylindrical articles, as they could not be separated one from the other easily, and their difference in diameter would be too apparent.

FIG. 34.

In *Fig. 34* is shown a photograph of a wash-basin just as it leaves the dies, where the body-wrinkles are very apparent, and where also the unevenness in contour of the flange plainly appears. This is caused by slight variations in the thickness and ductility of the metal, and also in the flatness of the holding-surfaces of the dies. As regards the latter, the variation from a perfect plane is partly caused by imperfect construction, but is in a greater degree due to their springing or bending out of flat by the unequal yielding of different parts of the press when the holding-pressure is brought upon it. Incidentally, it will be well to mention that the proper action of the drawing-surfaces depends not only upon their flatness, but upon extreme smoothness, and upon the grain of the polish of the metal being in a radial rather than in a circumferential direction. Referring again to body-wrinkles, I will mention that they may be partially avoided by an extra heavy pressure upon the flange, in which case the tensile strains upon the metal surrounding the punch tend to partly pull them out, as it were.

As upon the screen before you there happens to appear two photographs germain to the direction of the flow of particles from the flange to the body, I will here recur to the subject, explaining

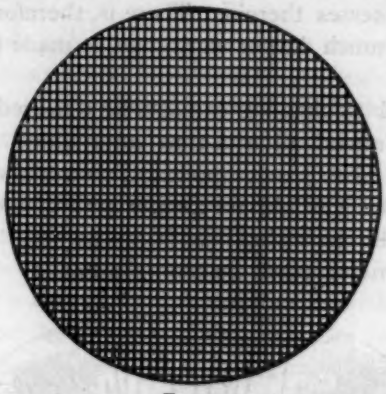


FIG. 35.

that *Fig. 35* is a blank cut from so-called "decorated tin," where a series of lines divide the surface into a number of small squares. The appearance of these squares after the metal has flowed to its

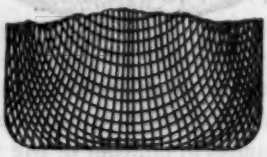
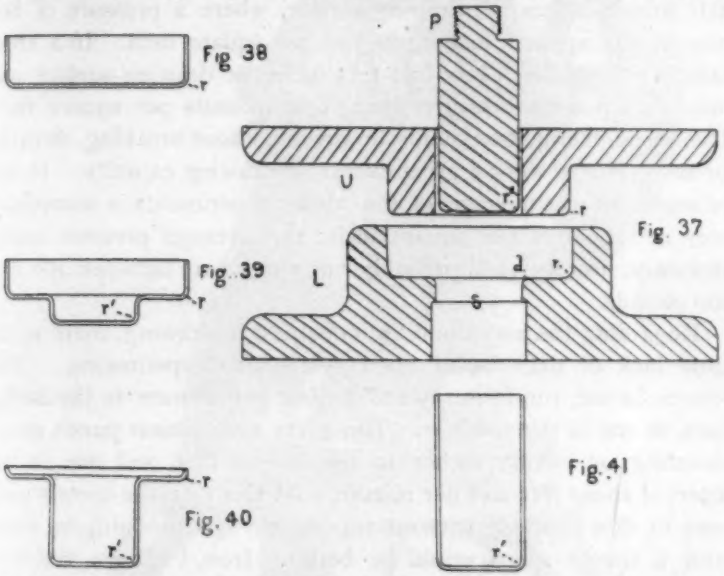


FIG. 36.

new shape is beautifully shown in *Fig. 36*, which is photographed direct from a piece of cylindrical work made from a blank like *Fig. 35*. This cup is shown in side view, and at the upper edge is seen the effect of uneven drawing incident especially to deep work. Such an edge needs trimming, but where the depth is not over about one-sixth of the diameter, it is usually good enough for commercial purposes without.

In *Fig. 37* is shown a pair of cylindrical "deepening" dies. They are in principle exactly like the plain dies, *Fig. 22*, except that instead of working a plain blank, they receive a cup which has been previously drawn at a first operation. Such a cup is shown in *Fig. 38*. It is placed within a recess in the lower die, which guides it exactly to place. The upper die is made of such a diameter as to ex-

actly fit inside of it, and the rounded corners upon both dies and punch, as shown at r, r and r', r', are made of such a curvature as to fit the work at the points marked by the same letters. Successive stages of this work, while being drawn deeper at this operation, are shown at *Figs. 39* and *40*, while at *Fig. 41* it is shown com-



pleted, as dropped through the die *L*. This process is known as "deepening," and can obviously be carried on in successive operations without limit, provided the metal does not harden, or can be annealed between operations. Thus, with brass, copper, black-iron and steel, etc., long tubes may be drawn from a flat sheet, as is instanced in some of the operations of cartridge-drawing, etc., these metals allowing the necessary annealing to be performed. With tin-plate, however, the coating of which would be spoiled by annealing, not more than two operations can usually be performed. With such material, a box may be obtained of a depth about equal to its own diameter, but not much deeper, and in such a case, the metal is made very brittle.

There are not many data available regarding the pressure per square inch for holding various kinds of metal between the surfaces of drawing-dies. I hope at some future time to make a systematic course of experiments, but so far have the records of only a few

informal ones. One of these showed that it took 4,600 pounds to hold without wrinkling the flange of a 5¾ x 1⅝-inch milk-pan. This had about twenty-three square inches of drawing-surface, and therefore required about 200 pounds per square inch. Another case was that of a small seamless blacking-box with two and one-half square inches of drawing-surface, where a pressure of 800 pounds was applied, making it 320 per square inch. In a third case, a $1\frac{9}{16}$ x ⅜-inch box had 1·35 inches of drawing-surface, and took 648 pounds pressure, being 480 pounds per square inch. This stood over 4,000 pounds, however, without breaking, showing for such shallow work a great excess of drawing capacity. It will be seen that the average of the above experiments is something over 400 pounds per square inch; the average pressure really necessary, however, will probably run somewhere between 200 and 400 pounds.

Regarding the maximum limit of speed in drawing, there is the same lack of data based upon systematic experiments. The presses in use, run from say ten strokes per minute in the larger sizes, to 200 in the smallest. This gives a maximum punch speed (counting on twenty inches in the former case and one in the latter) of about fifty feet per minute. At this rate, the metals used seem to flow properly without tearing, though probably in some cases a slower speed would be better. Iron, I believe, will flow faster than brass, but how much beyond the above speed it is practicable to go, must be left to the verdict of some future very interesting experiments.

In *Fig. 42*, now upon the screen, you will see a perspective view of an ordinary type of drawing-press, such as is usually employed for small work, say not over ten or twelve inches in diameter. In this the dies are shown set, the upper die at *U* and the lower at *L*. The "outer-slide-bar," carrying the upper die, is pushed downward until the latter is in contact with the blank, by means of cams upon the main-shaft, working against rollers in the slide-bar. These cams have a cylindrical portion of their surface so arranged as to hold the upper die perfectly still during the latter half of the descent of the punch and the first half of its upward return. The punch is attached to the "inner-slide-bar," which is driven by a crank and pitman in the usual way. Such presses are arranged with accurate adjustments for giving the proper pressure upon the

blanks and for making the punch descend to exactly the proper point. The outer-slide-bar is raised, in this case, by springs, which

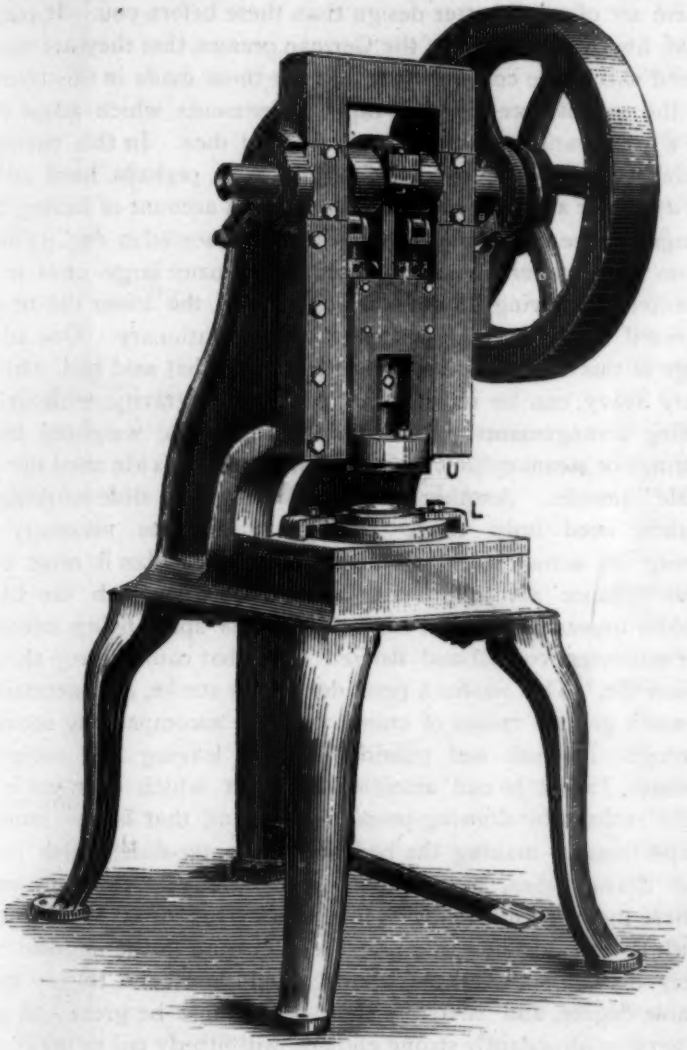


FIG. 42.

do not show in the picture. Sometimes "return" cams are used for this lifting. This view, *Fig. 42*, shows a press made in England. In *Fig. 43* is shown a much larger drawing-press, made in

Germany. For obvious reasons, of a non-advertising nature, I have not shown views of any American presses, although some of them are of much better design than these before you. It may be said, however, in favor of the German presses, that they are usually fitted with more conveniences than are those made in this country, in the way of extensive and rapid adjustments, which adapt them to a great variety of shapes and sizes of dies. In this particular point we may well copy the Germans, who, perhaps, have arrived at a greater state of perfection than we, on account of having been longer at the business. The machine represented in *Fig. 43* differs from the smaller one shown, and from many large ones in the market, by having the bed which carries the lower die to slide upward to meet the upper die, which is stationary. One advantage of this "bottom-slide" construction is that said bed, which is very heavy, can be returned to position by gravity, without any lifting arrangements, actuated either by cams, weighted levers, springs or steam-cylinders—all of which methods are used in "top-slide" presses. Another advantage is that the slide working the punch need only move through a distance necessary for doing its actual work, while with the other plan it must move this distance *plus* the waste space through which the blank-holder moves until the work is held—this space being necessary for removing conical and flanged work that cannot drop through lower die. This wastes a good deal of its stroke, and necessitates a much greater radius of crank, with the accompanying increased strength in shaft and gearing. Before leaving the subject of presses, I want to call attention to a fact which even yet is not fully realized by drawing-press makers, and that is, the immense importance of making the bed and the outer-slide, which carries the drawing-dies, of enormous *depth* relatively to their width. These members are really beams, usually supported at their ends, with the greatest working pressure occurring in the middle. It is very necessary that these beams should not bend to any appreciable degree, and therefore their depth must be great. A press otherwise abundantly strong enough, will utterly fail to make good work if these cross-members are allowed to spring so as to throw the face of the dies out of true when the pressure is brought upon them. In such cases, flange-wrinkles will commence to form in certain parts where the holding-surfaces happen to recede from each

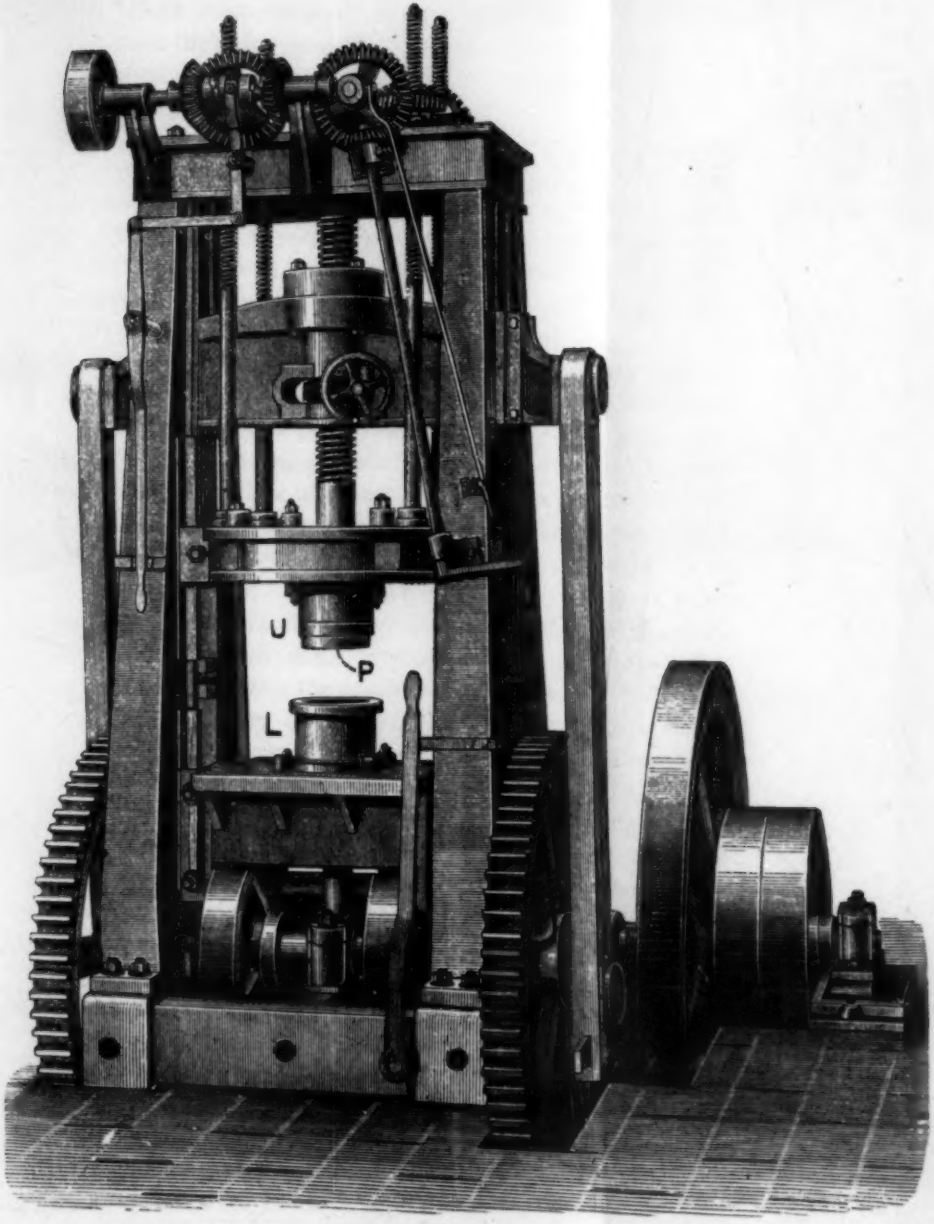


FIG. 43. GERMAN PRESS.

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other; and, when once formed, cannot possibly be removed. Worse than this, these wrinkles tend to force the dies still further apart and throw them into undulations of "springiness," so to speak, which is apt to entirely spoil the work.

While on the subject of presses, it may be well to mention a sort of mongrel drawing-press that is used for small work in some brass factories; where the outer-slide is driven by *cranks* instead of *cams*. This gives a simpler construction, but fails to properly "hold" the blank—except for an instant when the crank is passing its dead-centre. In the best modern practice such presses are giving way to those of the type shown in *Fig. 42*.

Recurring again to dies, I will mention that a certain method is frequently practised for drawing small articles, which are comparatively shallow, in an ordinary single-action press. This consists in using a strong spring-pressure for holding the flange of the metal from wrinkling. The dies used are generally constructed with a holding-ring surrounding the punch, and within the female cutting-die, which is pushed up by heavy springs, and answers as the lower holding-surface. The punch and female cutting-ring are fast in the lower die, while the upper die is the male cutting-die, with a recess in it, which does duty as the female forming-die. The flat lower face of this is the upper holding-surface. These are known as "spring drawing-dies," and answer a very good purpose, when small enough to make the power which they waste of little practical account.

It will naturally occur to the student of this subject that some easy method is desirable for determining the diameter of the blank for any given piece of drawn work, especially if its dies are to cut; as cutting edges are expensive to make—and to *alter* if guessed at and made wrong at first. Aside from lucky guessing, somewhat guided, perhaps by analogies from other approximately similar work that dies have been made for before, I have in my own practice used three principal methods to obtain this measurement of blank diameter.

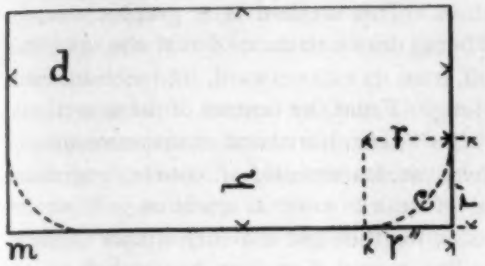
The first of these methods is the *tentative* one. It is the surest, but, in many cases, the most expensive. It consists in cutting blanks of as near as possible the right size and shape by guess, and trying them successively, modifying the shape of each to suit circumstances, until the proper shape of drawn work is produced.

For dies that do not cut, this isn't difficult, as the flat holding-surfaces can be made plenty large enough, and whatever gauging arrangements are to guide the blank, can be put on afterwards when its correct proportions are decided upon. In cutting dies, the female cutting-ring must be made separately, and left unfinished until the size and shape is ascertained. The male cutting-ring, which forms part of the upper holding-surface, must of course be made, but can be left plenty large enough until this trial has been completed.

The second method referred to, may be called the *gravitative*. It depends for its accuracy upon the principle, that the thickness of the metal in a piece of drawn work, is the same as it was in the original blank, which is in fact usually the case. My own method is to carefully weigh the sample piece of drawn work which is to be reproduced, and then, knowing the weight of one square inch of a piece of similar sheet-metal of exactly the same measured thickness, to calculate the number of square inches necessary in the blank and make its diameter to suit this given area. This method can obviously be practised only where a sample of the work is at hand, and where the blanks are circular in form. Certain inaccuracies may arise in the practise of this method, where there are sundry beads, corrugations, etc., near the centre of the piece of drawn work, which tend to let the metal stretch when the punch comes home in the die. Such action is properly embossing, rather than drawing, and stretches the metal thinner in certain places, which of course invalidates the accuracy of this system. It is, however, often useful for work whose contour is simple in form, near the central portions, where a drawing action does not take place.

The third method spoken of may be called the *mensurative*. This, too, depends upon equal areas and upon the thickness of the metal remaining the same. In the case of plain cylindrical work, a very simple formula, which I have worked out for the purpose, may be used. This is given in *Fig. 44*, equation III, for a box or cup whose corner at *m* is sharp, or nearly so, and in equation VI, for a round-cornered box. The latter formula is not theoretically accurate as regards equal areas, but serves an excellent practical purpose where the corner is not of too large a curvature—say with a radius not more than one-fourth the depth of the cup. The

FIG. 44.



Let, (in inches.)
d = Diam. of cup.
h = Height of cup.
r = Radius of corner.
c = Arc of 90°, with radius r.
a = Area bottom + sides
a = Area blank, also.
x = Diam. blank is to be cut.

$$a = \cdot 785\, d^2 + \pi dh., \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1.)$$

$$x = \sqrt{\frac{a}{\cdot 785}} = \sqrt{\frac{\cdot 785\, d^2 + \pi dh.,}{\cdot 785}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (2.)$$

$$x = \sqrt{d^2 + 4dh}, \text{ for sharp-cornered cup,} \quad . \quad . \quad . \quad . \quad . \quad . \quad (3.)$$

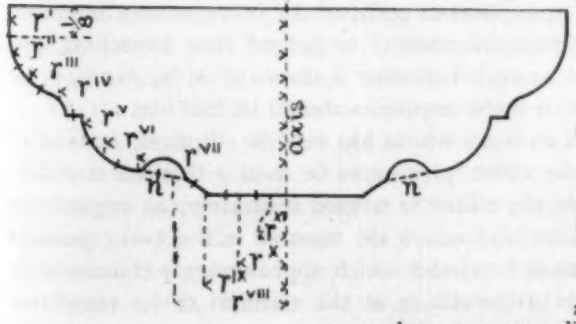
$$r' + r'' - c = \frac{r}{2} - \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4.)$$

$$2 = (r' + r'') - 2c = r - \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5.)$$

$$x = (\sqrt{d^2 + 4dh}) - r, \text{ about, for round-cornered cup; with small corner, say where } r < \frac{h}{4} \quad (6.)$$

diagram given in *Fig. 44* is a vertical axial section of a cylindrical box or cup, the same as was shown in *Fig. 26*. It is not worth while here to give the working-out of the formulæ, as by a close inspection, the figures will explain themselves.

FIG. 45.



Let (in inches.)
r^I, r^{II}, r^{III}, r^{IV}, etc. = Radii drawn to axis from centres-of-gravity of ⅛ inch segments of contour line.
$s = r^I + r^{II} + r^{III} + r^{IV}$, etc.; that is, the sum of the radii.
a = Area bottom + sides.
a = Area blank, also.
a^1 = Area of one zone whose average radius is r^I, r^{II}, r^{III}, etc.
x = Diam. blank is to be cut.

$$a' = 2\, r^1\, \pi\, \tfrac{1}{8}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1.)$$

$$a = 2\, s\, \pi\, \tfrac{1}{8} = \cdot 785\, s, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2.)$$

$$x = \sqrt{\frac{a}{\cdot 785}} = \sqrt{\frac{\cdot 785 s}{\cdot 785}} = \sqrt{s} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3.)$$

In *Fig. 45* is shown a method which I have devised for ascertaining the area of a piece of drawn work of irregular contour as regards its vertical section. This method is a graphic one, an exact profile of the work being drawn to scale of real size, and this contour-line being laid off, from its axis outward, into sections each exactly one-eighth inch long. From the centres of these sections, at the points marked r', r'', r''', etc., horizontal measurements are taken to the axis. These measurements, of course, represent various radii of the piece of drawn work in question. If we let the sum of them be called s, we then get the very simple formula given in equation III. The reason that just one-eighth of an inch was taken for the length of these segments of the contour-line was that it happened to reduce the equation to the simple form given, while any other length would have made it more complicated. The principle here involved is, obviously, that of the area of any zone being its width, multiplied by its circumference at a point representing the centre of gravity of its single cross-section. The points marked r', r'', etc., are, of course, not accurately in the centre of gravity of each of the little segments, but they are practically near enough so. The same principle occurs in this method as in the last-mentioned one regarding places in the metal which will stretch thinner when formed to shape, like deep beads, or other indentations. This trouble may be mostly neutralized, however, by bridging over them, so to speak, in making the contour-line; that is, by running the latter across from point to point of the corrugations instead of following their curves, wherever it is judged that stretching will take place. This amended contour is shown at *n*, *n*, *Fig. 45*, by dotted lines, and on it the segments should be laid out.

In making drawn work whose top view is elliptical, instead of round, the formulæ above given may be used with some modifications. To do this, the ellipse is treated separately, as regards its short and long axes, and values are inserted in the two equations which would be used for circles which approximately coincide with the sides and ends of the ellipse, at the terminii of its respective axes.

In making rectangular work with round corners, some idea of the shape of the blank may be obtained by treating the corners as belonging to a circle of the proper diameter, while the sides of

the rectangle (which properly are not drawn at all, but only bent to shape), may be treated nearly by actual measurement, as in them very little stretching takes place. As regards the corners, however, the tentative method is the safest wherever it is possible to use it.

It may be of interest to state that certain kinds of work are drawn from whole sheets of metal, wherever such sheets are only a little larger than the blank which would otherwise be used, and the cutting to shape is done in a pair of "trimming"-dies afterward. This method is frequently used for such work as wash-boiler bottoms, dust-pans, halves of toy animals, etc, and gives an accuracy of edge contour not attainable the other way.

As an accessory to the process of drawing, the old-fashioned process of spinning is sometimes used, for finishing certain details of shape which cannot be done in the dies. The drop-press is also occasionally brought into requisition for finishing certain shapes. Much more common than either of these, however, is the process of roller-spinning before referred to. This is very much more rapid than the old-fashioned hand-spinning with a burnisher, and is done very quickly by a cheap quality of labor. It is used for crushing out such body-wrinkles as were shown you in *Fig. 34;* in wash-bowls, conical pans and such work. One or more of these articles are placed upon a steel chuck, without even stopping its revolution, and being pushed up solidly by a loose pad upon the dead-spindle of the lathe, so that they are driven by the friction of the chuck, a hardened steel roller, mounted upon a slide rest is rapidly passed once over them, under considerable pressure, and thus the wrinkles are entirely removed.

On the table before me, you will see a large number of specimens of drawn work of various proportions and of several materials. These I shall be glad to show in detail to anyone interested, after the lecture is over. The larger articles on my right were kindly loaned me by Mr. George Melloy, of this city, and very well represent the general line of commercial stamped-ware hinted at in *Figs. 1* to *18*. Perhaps the most interesting among them is this milk-can, the lower part of which is drawn seamless in one piece. It is about a foot in diameter by nearly two feet deep, and was drawn and deepened at three or four operations with annealings between and the tinning afterward.

With regard to the future possibilities of this interesting process of drawing metals, we probably can form but a primitive idea. Already, articles as large as soda-water fountains and the halves of kitchen-boilers are drawn from a flat sheet; and it would be simply a matter of first cost for plant, to draw large steam-boilers in the same way. There would certainly be no real difficulties, except the expense of plant, in drawing such things as bath-tubs, boats of small sizes, etc., by precisely similar methods to those I have indicated this evening.

Of the real value of this invention, I think the public have a very inadequate idea—perhaps because there is so little generally known about it, the practise of the art being mostly confined to a few large and very secretive-minded factories. To it mainly, however, we owe the wonderful cheapness, abundance and variety of the household utensils, which help in some degree to lighten the burdens of toiling millions of wives and mothers the world around. If, like Abou-Ben-Ahdem, the man who makes to grow two blades of grass where grew one before, is a lover of his fellow-men, with what laurels shall we crown the brow of him, who in so many a busy kitchen has placed, not *two*, but *ten* pots, and kettles, and dishes, and pans, where but one might have been attainable, were it not for this scientific and beautiful art.

'Tis true, we may take another view and wonder how much this process has also contributed to human misery by producing cheap *cartridges*, but shall we not, with optimistic mind, think of those things that make war more deadly, as warnings which will teach men to go to war no more, and thus help forward the reign of universal peace?

An Interesting Monument.—M. Clermont-Ganneau has communicated to the Academy of Inscriptions and Belles-Lettres a note relative to a discovery made by him in an old building at Jerusalem. It was a block of stone, with a Greek inscription signifying that any stranger who should have passed that limit would be condemned to death. It is evidently a fragment of one of the posts which formed, in the temple built by Herod, a dividing line between the exterior enclosure of the Gentiles and the inner precinct reserved for the Jews. It will be remembered that St. Paul barely escaped stoning when he was accused of having introduced Greeks into the inner circle with himself. The stone has been removed to Constantinople, but a cast has been taken, which will be preserved in the Museum of the Louvre. —*Cosmos, Aug. 24, 1885.*

A NEW PROCESS FOR THE PRODUCTION OF THE METALS OF THE ALKALIS.

BY HAMILTON Y. CASTNER, of New York.

[*A Paper read before the Chemical Section of the* FRANKLIN INSTITUTE, *October 12, 1886.*]

MR. H. W. JAYNE, President, in the Chair.

DR. WAHL, Secretary of the INSTITUTE, presented the following communication from Mr. Castner.

MR. PRESIDENT AND GENTLEMEN:—I shall first proceed to give a brief description of the process heretofore employed for manufacturing the alkali metals, together with the defects of the same, which prevent an economical production of metal, before explaining the method I have invented for their reduction, and its advantages over the older process. Although in the following paper mention is only made of sodium, the same remarks are intended to apply to potassium, the process being practically alike in the production of either metal. The method formerly used consists in igniting, at an intense heat, an intimate mixture of nine parts of sodium carbonate, four parts of charcoal, and one part of lime in wrought-iron vessels, cylindrical in form, placed horizontally in a furnace, the said cylinders being furnished with a small tube to conduct the metallic vapors and gases produced during the reduction, into the attached condenser, wherein the vapors are condensed and the sodium obtained. The cylinders must be constructed of wrought-iron, this being the only metal possible to use that will stand the heat, and the dimensions of the same not exceed a diameter of 6 inches, or a length of 5 feet. The mixture of sodium carbonate, charcoal and lime must be finely ground and calcined, to render it more compact, previous to placing it in the cylinders. Lime is added to make the mass refractory, otherwise the alkali would fuse when the charge is highly heated, and separate from the light, infusible carbon. The carbon must be in the proportion to the sodium carbonate as four is to nine, which is found needful in practice, so as to assure each particle of soda in the refractory charge having an excess of carbon directly adjacent or in actual contact. Notwithstanding the well-known fact that sodium is reduced from its oxides at a degree of heat but slightly

exceeding the reducing point of zinc-oxide, the heat necessary to accomplish reduction by this process and to obtain even one-third the metal contained in each charge, closely approaches the melting-point of wrought-iron. Any process devised for the manufacture of sodium, by which its cost could be reduced, would have to be an improvement over the older method in one or more of the following directions, namely:

(1.) The process should be more simple in its details, and not require the care and management necessary in carrying on the process or method now used.

(2.) Performing the reduction at a comparatively low temperature and so save in the fuel and prevent the excessive destruction of iron, which at present stands for one-half the cost of the sodium produced.

(3.) By increasing the yield of sodium, as in the old process, when one-third the metal contained in the charges, is obtained, the result is considered very satisfactory.

The process which I employ consists in reducing either the hydrate or carbonate of an alkali, when in a fused state, at moderate temperatures, by the use of the carbide of a metal or its equivalent, whereby an excess of carbon is avoided and the use of lime is rendered unnecessary. The reducing substance, due to its composition and gravity, remains below the surface and is therefore in direct contact with the fused alkali. By the equivalent of the carbide of a metal, I mean, a mechanical compound of carbon and metal from which the metal cannot be separated, excepting by the aid of acids or intense heat. Such a compound I produce by coking a mixture of tar and iron (previously reduced in a fine state of division, by carbonic oxide or hydrogen). From experience, such proportions of tar and iron are used, as will produce, when the mixture is coked, a heavy mass of metallic coke, having about the composition of, iron seventy per cent. and carbon thirty per cent., equivalent to the formula, $Fe\ C_2$. This mechanical compound, after being ground, is ready for use and consists of fine particles of iron, coated with carbon, fully answering the purposes of a true carbide. I prefer to use caustic soda in the preparation of sodium, on account of its fusibility, and with it mix such quantity of the so-called "carbide;" that the carbon contained in the mixture shall not be in excess of the amount, theoretically required to

reduce all the soda to sodium, according to the following reaction,

$$3\,NaHO + FeC_2 = 3\,Na + Fe + CO + CO_2 + 3\,H;$$ or:

to every 100 pounds of pure caustic soda, fifteen pounds of "carbide," containing about twenty-two pounds of carbon, is added. The treatment of this mixture is carried on in large cast-iron crucibles, in a furnace, the general arrangements of which are as follows: The heating space of the furnace is divided into separate chambers, the dimensions of the same depending upon the size of the crucibles to be heated, and the number of these compartments are in proportion to the capacity of production desired for the furnace. An aperture is provided in the bottom of each chamber, through which the crucible may be raised by mechanical means into its position in the furnace. The necessary cover for the crucible is fixed stationary in each chamber, and from this cover projects the tube to the outside of the furnace into the receptacle for the condensation of the metallic vapors. When operating, the crucibles are charged with the mixture, made as before described, placed upon the lift, which is situated directly below the aperture made in the bottom of the chamber, and raised into the furnace. The edges of the covers are made convex, while the edges of the crucibles are concave, so that when the crucibles are raised the edges come together, and, being held from below, form a tight joint, preventing the exit of gas and vapor, excepting through the tube provided from the cover. Gas, which is used as a fuel in connection with heated air, is allowed to enter the chamber, after the crucible containing the charge is in place, and the reduction and distillation commences as soon as the crucible contents have reached the temperature of 1,000° C., the sodium being reduced in the crucible and distilled therefrom into the condenser, by passing through the tube projecting from the crucible cover. As soon as the operation is finished, the crucible is lowered and a new one containing a fresh charge is raised in its place, while the crucible just removed is cooled, cleaned and recharged. The appliances, which hold the cover in place are so arranged, that the cover may be removed whenever necessary without interrupting the process, which is practically continuous. By avoiding the careful mixing and calcining of ingredients, preparatory to charging the cylinders, and in carrying out generally the mechanical

part of the old process, the details of which require the most careful management, the method just described will be seen to have many advantages. As the charge is fused, the alkali and reducing material are in direct contact, and this fact, together with the aid rendered the carbon by the fine iron, in withdrawing the oxygen from the soda, fully explains the chemical reasons why the reduction is accomplished at a moderate temperature. Furthermore by reducing the metal from a fused mass, in which the reducing agent remains in suspension, the operation can be carried on in crucibles of large diameter, the reduction taking place at the edges of the mass, where the heat is greatest and the charge flowing thereto from the centre to take the place of that reduced. By the old process, the heat required to penetrate to the centre of the refractory charge and reduce the soda there situated in addition to the heat absolutely needful to bring about reduction, necessitates the use of wrought-iron vessels, and even when these are made small in diameter, which partially removes this great disadvantage of the method, the expensive cylinders are rapidly rendered worthless from the effects of the intense heat.

In doing away with the use of lime and an excess of carbon, the main causes which have hitherto prevented a full yield of metal are removed, and thus, with the aid of other advantages described, I am enabled to obtain fully ninety per cent. of metal, instead of thirty per cent., as formerly. By the old process, lime must be added to prevent fusion, to insure any reduction, yet at the same time it forms, with a portion of the soda, the compound known as soda-lime, and from this substance carbon reduces sodium only at the most intense heat. In practice, according to the old method, four pounds of carbon are used to every nine pounds of sodium carbonate. This is twice the amount theoretically required to reduce all the sodium, even assuming the gas resulting from the reduction to be wholly carbonic-oxide. When, however, but one-third the total amount of sodium is all that is obtained from a charge, the proportion between the sodium produced and carbon used becomes as one is to six. The effect of an excess of carbon in the mixture, which, as previously explained, is really necessary, is to produce an excessive amount of carbonic-oxide, and this, together with the excess of carbon, combines with the metallic vapors of sodium, forming various compounds, from which

the metal cannot be distilled. By reducing caustic-soda with the carbide of a metal, or its equivalent, and using only sufficient carbon to carry out the reaction stated above, the gases given off consist of hydrogen, carbonic-oxide and carbonic-acid, which mixture has little or no effect upon the vapors of sodium. The crucibles, after treatment, contain a small amount of carbonate of soda and all the iron of the "carbide" still in a fine state of division, together with a very small percentage of carbon. These residues in the crucibles are treated with warm water, and the solution of soda evaporated to recover the carbonate of soda, while the fine iron is dried, mixed with tar and coked to produce more of the so-called "carbide equivalent."

TURBINES.

By J. Lester Woodbridge, M. E., Stevens Institute of Technology.
[With an Introduction by De Volson Wood, Professor of Mechanical Engineering.]

(INTRODUCTION.)

To the Committee on Publications:

I forward to you, for publication, the graduating thesis of Mr. Woodbridge, upon "Turbines." The first well-grounded theory of these wheels was by M. Poncelet, who read a paper upon this subject before l'Academie des Séances, Paris, entitled "La Théorie des Effets Mécaniques de la Turbine-Fourneyron," published in *Comptes Rendus*, Paris, 1838. This solution was so thorough and elegant that it is often referred to as "historical" and "classical." The analysis was founded on the principles of work and energy, and his methods have been followed by many writers since his day. Rankine, in his *Steam Engine and other Prime Movers*, has given a partial solution of a special case founded on the principle of the ***Moment of the Momentum***, and he has been followed by Unwin, in his article on "Hydro-mechanics," in the *Encyclopædia Britannica*, IX edition. It will be seen that Mr. Woodbridge's solution is founded upon the resolution of the pressures of elementary volumes and their moments, and is more general than either of the preceding, if not the most general solution of the frictionless turbine yet made. Yours truly,

De Volson Wood, *Prof. Mech. Eng.*

Hoboken, June 25, 1886.

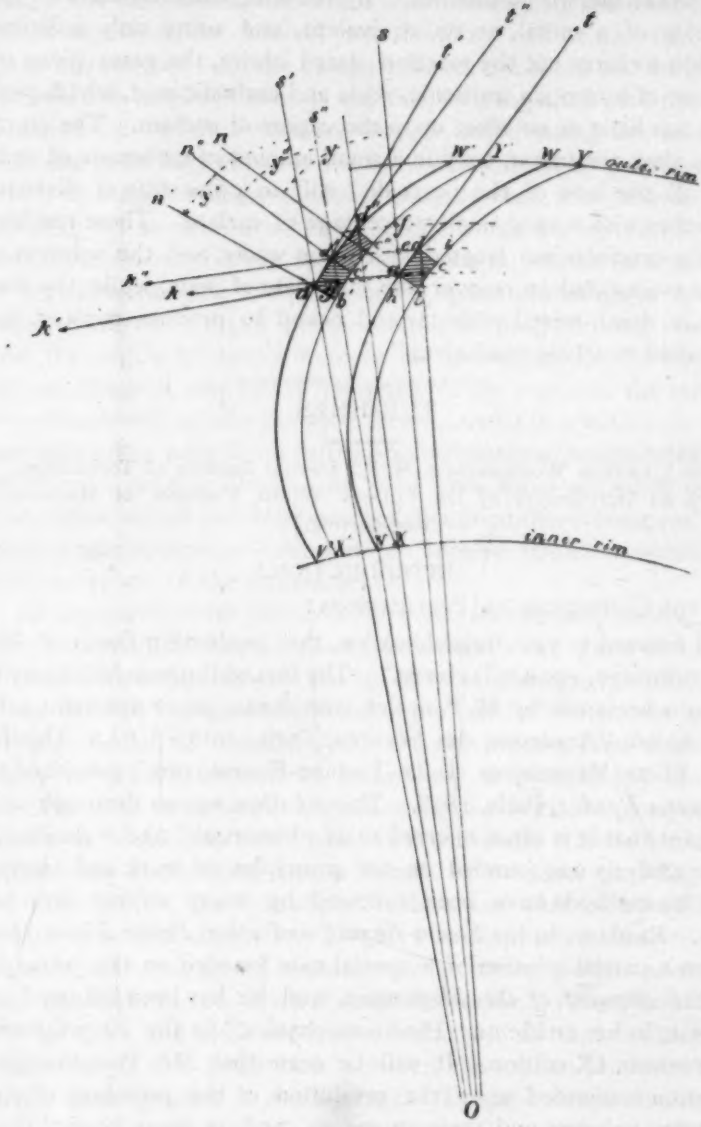


FIG. 1.

I propose to discuss the action of turbines in general. Consider first the water after it has entered the wheel and is passing

along its vanes. Conceive the water to be divided into an infinite number of filaments by vanes similar to those of the wheel, but subjected to the condition that, at each point, their width id, *Fig. 1*, measured on the arc, whose centre is O, shall subtend at the centre a constant angle $d\theta$. Conceive each filament to be divided into small prisms, whose bases are represented by the shaded areas $a'b'c'd'$, $d'c'c''d''$ and $abcd$, by vertical planes normal to the vanes making the divisions ae, ef, intercepted on the radius by circles passing through the consecutive vertices on the same vane a', d', d'', etc., equal.

Let ρ = the radius vector;
x = the height of an elementary prism;

then,

$d\rho = ae$, ef, etc.;
$\rho\, d\theta\, d\rho = abcd$, etc., = area of the base of an infinitesimal prism;
$x\, \rho\, d\theta\, d\rho$ = volume of an infinitesimal prism;
$x\, \delta\, \rho\, d\theta\, d\rho = m$ = the mass of prism, δ being its density;
$\gamma = s\, a\, n$ = angle between the normal to the vane at any point, and the radius $O\,a$ prolonged through that point;
v = velocity of a particle along the vane at ρ;
ω = the uniform angular velocity of the wheel, and
p = the pressure of the water at the point ρ.

For the element of time, dt, we will take the time occupied by one of the liquid prisms in passing along the vane through a distance equal to its own length, or, outwardly, a distance $d\rho$, thus making t a function of ρ, the latter being considered the independent variable. We have

$$\frac{dt}{d\rho}\, d\rho = \frac{d\rho}{\frac{d\rho}{dt}} = \frac{d\rho}{v \sin\gamma}.$$

Let $a\,a'$ be the distance passed through by this element circumferentially in the time dt, then

$$a\,a' = \omega\, \rho\, dt = \omega\, \rho\, \frac{dt}{d\rho}\, d\rho$$

and the particle $a\,c$ will, at the end of time dt, be at $a'\,c'$.

To find the reaction of a particle moving on a curved path, let the particle move from P, *Fig. 2*, along a curve to the consecutive

point, P', changing its direction by an angle, $d\gamma$, from PA to $P'B$. The velocity along PA being v, it will have acquired the

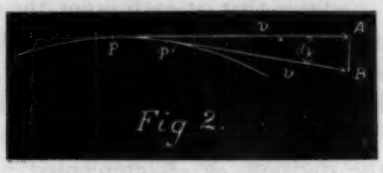


Fig 2.

velocity, $v\,d\gamma$, perpendicular to PA, in time dt, and its acceleration in the same direction will be $\frac{v\,d\gamma}{dt}$, and the force $= m\,v\,\frac{d\gamma}{dt}$ where m is the mass of the particle. That is, *the reaction of a particle, the direction of whose motion is being changed, is equal to its momentum multiplied by the rate of the angular change of its motion, and is in a direction opposite to that in which the change takes place.*

The mass m will have two motions: one along the vane, the other with the wheel perpendicular to the radius. By changing its position successively in each of these directions, both its velocity with the wheel and its velocity along the vane may suffer changes both in *amount* and *direction*, as follows:

(I.) By moving from a to a', *Fig.* 1, in the arc of a circle—

(1.) $\omega\rho$ may be increased or diminished;

(2.) $\omega\rho$ may be changed in direction;

(3.) v may be increased or diminished;

(4.) v may be changed in direction.

(II.) By moving from a' to d' along the vane—

(5.) $\omega\rho$ may be increased or diminished;

(6.) $\omega\rho$ may be changed in direction;

(7.) v may be increased or diminished;

(8.) v may be changed in direction.

These changes give rise to corresponding reactions, as follows:

(No. 1.) By the conditions imposed, $\omega\rho$ will be constant, and hence the *reaction* $= 0$.

(No. 2.) By moving from a to a', the velocity $\omega\rho$ is changed in direction from ak to $a'k'$ in the time dt. The momentum is $m\,\omega\rho$, and the rate of angular change is

$$\frac{kak'}{dt} = \frac{\omega\,dt}{dt} = \omega,$$

and hence the reaction will be $m\omega^2\rho$ in a direction radially outward. This is the *centrifugal force*, as designated by most writers. Resolving into two components, we have

$$m\,\omega^2\,\rho\,\sin\gamma \text{ along the vane,}$$
$$m\,\omega^2\,\rho\,\cos\gamma \text{ normal to the vane.}$$

(No. 3.) According to the conditions imposed, this value of v remains constant, hence, for this case, the reaction will be zero.

(No. 4.) In moving from a to a' the velocity along the vane, v, is changed in direction from ak to $a'k'$ at the rate ω as in No. 2. The momentum is mv, and the force will be $mv\omega$, which acts in the direction na, and being resolved, gives

$$0 \text{ along the vane,}$$
$$-mv\omega \text{ normal to the vane.}$$

(No. 5.) In passing from a' to d', the *increase* of $\omega\rho$ will be $\omega\,d\rho$, in a time dt, and the reaction will be

$$m\omega\frac{d\rho}{dt},$$

in a direction tangential to the motion of the wheel but backwards, and its components will be

$$m\omega\frac{d\rho}{dt}\cos\gamma \quad \text{along the vane,}$$
$$-m\omega\frac{d\rho}{dt}\sin\gamma \quad \text{normal to the vane.}$$

(No. 6.) In passing from a' to d', $\omega\rho$ will be changed in direction by the angle

$$a'\,O\,d' = \frac{a'\,g}{\rho} = \frac{d\rho\cot\gamma}{\rho},$$

and the rate of angular change will be

$$\frac{\cot\gamma}{\rho}\cdot\frac{d\rho}{dt},$$

and the momentum will be

$$m\omega\rho;$$

hence the reaction will be

$$m\omega\cot\gamma\frac{d\rho}{dt},$$

which acts radially inward, and its components are

$$-m\,\omega\cos\gamma\,\frac{d\rho}{dt} \quad \text{along the vane,}$$

$$-m\,\omega\cot\gamma\cos\gamma\,\frac{d\rho}{dt} \quad \text{normal to the vane.}$$

(No. 7.) By moving from a' to d', v will be increased by an amount

$$\frac{dv}{d\rho}\,d\rho,$$

in the time dt, and the reaction will be

$$m\,\frac{dv}{d\rho}\cdot\frac{d\rho}{dt};$$

which acts backward along the vane, and its components are

$$-m\,\frac{dv}{d\rho}\cdot\frac{d\rho}{dt} \quad \text{along the vane,}$$

$$0 \quad \text{normal to the vane.}$$

(No. 8.) In passing from a' to d', v is changed in direction by two amounts: (1.) The angle γ changes an amount

$$-\frac{d\gamma}{d\rho}\,d\rho,$$

and (2.) the radius changes in direction an amount

$$\frac{d\rho\cot\gamma}{\rho},$$

as in No. 6; hence the total change will be the sum of these, and the *rate* of change will be the sum divided by dt, which result, multiplied by the momentum mv, will give the reaction, the components of which will be

$$0 \quad \text{along the vane,}$$

$$mv\left[\frac{\cot\gamma}{\rho}\cdot\frac{d\rho}{dt}-\frac{d\gamma}{d\rho}\cdot\frac{d\rho}{dt}\right] \quad \text{normal to the vane.}$$

This completes the reactions. Next consider the *pressure in the wheel.* The *intensity* of the pressure on the two sides ab and cd differs by an amount

$$dp=\frac{dp}{d\rho}\,d\rho.$$

The area of the face is $dc\times x=x\,\rho\,d\,\theta\,\sin\gamma$, and the force due to the difference of pressures will be

$$x\,\rho\,d\,\theta\,\sin\gamma\,\frac{dp}{d\rho}\,d\rho.$$

If dp is positive, which will be the case when the pressure on de exceeds that on ab, the force acts backwards, and the preceding expression will be *minus* along the vane. In regard to the pressure normal to the vane, if a uniform pressure p existed from one end of the vane VW to the other, the resultant effect would be zero, since the pressure in one direction on VW would equal the opposite pressure on XY, *Fig.* 1. If, however, in passing from d to a, the pressure increases by an amount $-dp$, since Va is longer than Xb, the pressure on Va will exceed that on Xb by an amount

$$-dp\,x \times ah = -dp\,.\,x\,.\,\rho\,d\theta\cos\gamma = -x\rho\cos\gamma\,d\theta\frac{dp}{d\rho}d\rho.$$

Collecting these several reactions, we have

NORMAL TO THE VANE.	ALONG THE VANE.
(2.) $+ m\omega^2\rho\cos\gamma.$	$+ m\omega^2\rho\sin\gamma.$
(4.) $- m\omega v.$	0.
(5.) $-m\omega\sin\gamma\frac{d\rho}{dt}.$	$+ m\omega\cos\gamma\frac{d\rho}{dt}.$
(6.) $-m\omega\cot\gamma\cos\gamma\frac{d\rho}{dt}.$	$-m\omega\cos\gamma\frac{d\rho}{dt}.$
(7.) 0	$-m\frac{d\rho}{dt}\cdot\frac{dv}{d\rho}.$
(8.) $+ m\,v\left[\frac{\cot\gamma}{\rho}\cdot\frac{d\rho}{dt}-\frac{d\gamma}{d\rho}\cdot\frac{d\rho}{dt}\right].$	0
(9.) $-x\rho\cos\gamma\frac{dp}{d\rho}d\rho\,d\theta.$	$-x\rho\sin\gamma\frac{dp}{d\rho}d\rho\,d\theta.$

The sum of the quantities in the second column, neglecting friction, will be zero; hence

$$m\omega^2\rho\sin\gamma - m\frac{d\rho}{dt}\cdot\frac{dv}{d\rho} - x\rho\sin\gamma\frac{dp}{d\rho}d\rho\,d\theta = 0 \qquad (1)$$

Substituting

$$\frac{d\rho}{dt} = v\sin\gamma, \text{ and } x\rho\,d\theta\,d\rho = \frac{m}{\delta}$$

and dividing by $m\sin\gamma$, we have

$$\omega^2\rho\,d\rho - \frac{1}{\delta}dp = v\,dv. \qquad (2)$$

Integrating,

$$\left[\frac{1}{2}\,\omega^2\rho - \frac{p}{\delta}\right]_{\text{limit}}^{\text{limit}} = \left[\frac{1}{2}\,v^2\right]_{\text{limit.}}^{\text{limit.}} \tag{3}$$

The sum of the quantities in the first column gives the pressure normal to the vane, which, multiplied by $\rho \sin\gamma$, gives the moment. This done, we have, after substituting as above,

$$d^2M = mv\sin\gamma\left[\begin{array}{l}\omega\rho\left(\frac{\rho}{v}\,\omega\cos\gamma - 2\right) - \rho\, v\sin\gamma\,\frac{d\gamma}{d\rho} \\ + v\cos\gamma - \rho\,\frac{\cos\gamma}{v\delta}\,\frac{dp}{d\rho}\end{array}\right].$$

Putting $mv\sin\gamma = \frac{\delta}{2}\,\frac{Q}{\pi}\,d\rho\,d\theta$, where Q is the quantity of water flowing through the wheel per second, and integrating in reference to θ between 0 and 2π, we have

$$dM = \delta\, Q\left[\omega\rho\left(\frac{\rho}{v}\,\omega\cos\gamma - 2\right) - \rho\, v\sin\gamma\,\frac{d\gamma}{d\rho} + v\cos\gamma - \rho\,\frac{\cos\gamma}{v\delta}\,\frac{dp}{d\rho}\right]d\rho$$

Multiplying (2) by

$$\frac{\rho}{v}\cos\gamma,$$

we have

$$\frac{\omega^2\rho^2}{v}\cos\gamma\,d\rho - \frac{\rho\cos\gamma}{v\delta}\,\frac{dp}{d\rho}\,d\rho = \rho\cos\gamma\,\frac{dv}{d\rho}\,d\rho$$

which substituted above gives

$$dM = \delta\, Q\left[-2\omega\rho\,d\rho + \rho\cos\gamma\,\frac{dv}{d\rho}\,d\rho + v\cos\gamma\,d\rho - \rho\, v\sin\gamma\,\frac{d\gamma}{d\rho}\,d\rho\right] \tag{4}$$

and integrating,

$$\begin{aligned} M &= \delta\, Q\,[-\omega\rho^2 + \rho\, v\cos\gamma] \\ &= -\delta\, Q\,\rho\,[\omega\rho - v\cos\gamma]_{\text{limit.}}^{\text{limit.}} \end{aligned} \tag{5}$$

But $\omega\rho - v\cos\gamma$ is the circumferential velocity in space of the water at any point, and $\delta\, Q\,\rho\,[\omega\rho - v\cos\gamma]$ is the moment of the momentum, hence, integrating between limits for inner and outer rims, *the moment exerted by the water on the wheel equals the difference in its moment of momentum on entering and leaving the wheel.* Thus we have deduced an expression which some writers have made the basis of their investigations.

Let the values of the variables at the entrance of the wheel be $\rho_1, \gamma_1, v_1, p_1$, and at exit $\rho_2, \gamma_2, v_2, p_2$.

Equations (3) and (5) become

$$\frac{1}{2}\omega^2(\rho_1^2-\rho_2^2)-\frac{p_1-p_2}{\delta}=\frac{1}{2}(v_1^2-v_2^2) \quad (6)$$

$$M=\delta\, Q\,[\omega(\rho_1^2-\rho_2^2)-\rho_1 v_1 \cos\gamma_1+\rho_2 v_2 \cos\gamma_2] \quad (7)$$

$$\therefore\ U=M\omega=\delta\, Q\,\omega[\omega(\rho_1^2-\rho_2^2)-\rho_1 v_1 \cos\gamma_1+\rho_2 v_2 \cos\gamma_2] \quad (8)$$

Equation (8) gives the work per second in terms of the known quantities δ, ω, ρ_1, γ_1, ρ_2, γ_2, and three quantities Q, v_1, v_2 as yet unknown. These three quantities are, however, connected by the condition that the quantity of water flowing through all the sections radially is constant. Calling a_1 the entire area of all the orifices at the entrance of the wheel ($= 2\pi\rho_1 x_1$), and a_2 those at exit ($= 2\pi\rho_2 x_2$), we have

$$Q=a_1 v_1 \sin\gamma_1=a_2 v_2 \sin\gamma_2 \quad (9)$$

which reduces the number of unknown quantities to one.

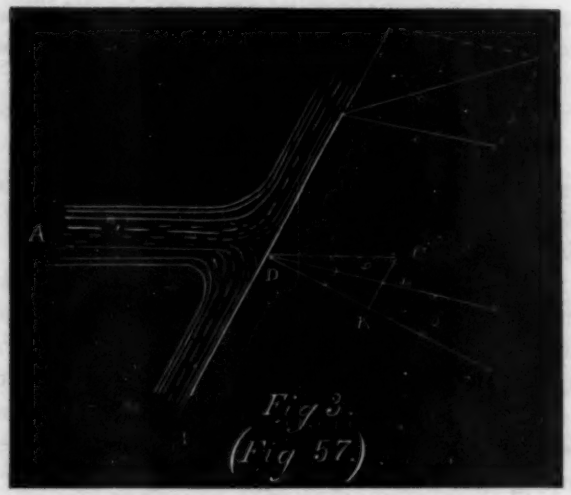


Fig 3.
(Fig 57.)

Equation (6) is the equation of the motion of the water in the wheel. Besides the velocities v_1 and v_2, it contains p_1 and p_2.

Let p_a = the atmospheric pressure,

h = the mean depth of the wheel below the surface of tail-race,

$p_t = \delta gh$ = the pressure due to the flooding of the tail-race;

then $p_2 = p_a + p_t$.

The pressure p_1, where the water passes from the guide blades into the wheel, is unknown. Another condition is necessary, which may be found by considering the passage of the water from the guide plates into the wheel. Here it must be observed that the path of a liquid stream, either in space or relative to some moving object, is always a *continuous curve*, and never contains a sharp angle, the motion being continuous—a principle confirmed both by theory and experience. This granted, we can show the fallacy of some statements of Professor Rankine, in regard to the impulse of a stream of water on a vane. Take the case given on page 163 of Rankine's *Steam Engine, Fig. 57*, and discussed on page 169, Case V. I copy his diagram and lettering, adding a few lines that he omitted.

On page 169, he says, "In this case the easiest method of solution is the following:

"Let $v' = D\,C$, *Fig. 3*, be the velocity of the jet relatively to the vane. Let the angle $C\ D\ K$, which it makes with the normal to the vane, be denoted by θ. Resolve v' into two components, viz.:

$$D\,K \text{ normal to the vane} = v' \cos\theta,$$
$$K\ C \text{ along the vane} = v' \sin\theta.$$

"Then, according to the supposition that friction is insensible, $K\,C$ is not affected in magnitude by the vane, but $D\,K$ is entirely taken away."

Now, as shown, the stream will move in a curve on account of the self-cushion of water, and it is a well-established principle that in a frictionless fluid, *the relative velocity of a particle suffers no loss in passing around a curve*, if subjected to no other forces than the reaction of the guiding surfaces; or, in other words, if the deviation be free. Therefore, if the relative velocity of the jet was v' before impinging, the velocity along the vane after impinging will also be v', and not $v' \sin\theta$, as Rankine states it. That his solution is erroneous, may also be shown by the fact that his expression for the energy imparted to the wheel added to that lost, does not equal the original energy. Thus, according to his equation (47), the energy exerted on the wheel is

$$P\,u = D\,Q\,\frac{u\,v'\cos\theta\cos\delta}{g}.$$

To find the energy lost: if $v' \sin \theta$ be the velocity along the vane, and u the velocity with the vane, then will the velocity on leaving the vane be the resultant of these velocities, or

$$\sqrt{v'^2 \sin^2 \theta + u^2 + 2\, u\, v' \sin \theta \sin \delta},$$

and the energy will be

$$\frac{D\,Q}{2\,g}\left[v'^2 \sin^2 \theta + u^2 + 2\, u\, v' \sin \theta \sin \delta\right],$$

which, added to the energy exerted, gives

$$\frac{D\,Q}{2\,g}\left[v'^2 \sin^2 \theta + u^2 + 2\, u\, v' \cos \varphi\right], \qquad (a)$$

where $\varphi = \theta - \delta =$ the angle between the velocities u and v'. Now, the actual velocity before striking the vane was the resultant of u and v', or

$$\sqrt{u^2 + v'^2 + 2\, u\, v' \cos \varphi},$$

and the total energy was

$$\frac{D\,Q}{2\,g}\left[u^2 + v'^2 + 2\, u\, v' \cos \varphi\right] \qquad (b)$$

which exceeds equation (a); hence, according to Rankine's solution, there would be a disappearance of energy, which is contrary to the law of the conservation of energy. His error will at once be apparent by making the vane normal to the stream, in which case θ will be zero, and $D\,K = v'$, and $K\,C$ would become zero, whereas it should be v' to agree with the statement above.

Rankine makes no mention of the fact he has plainly shown in the figure—that of a division of the stream into two streams upon striking the vane, but treats it as if it were guided as in a bent tube.

On page 173, Art. 147, he again refers to the subject, and divides the pressure exerted on the vane into two parts:

"(1.) The pressure arising from the changing of the direct component $v \cos \alpha$ of the velocity of the water into the velocity of the vane.

"(2.) The term reaction is applied to the additional action depending on the direction and velocity with which the water glances off from the vane."

This latter is the reaction due to the change in direction of the relative velocity of the jet. It is the sole cause of the pressure

exerted in all cases of free deviation, and I fail to see any meaning in his so-called "direct action" as here used. This conclusion agrees with the principles in Wood's *Mechanics of Fluids*.

Rankine remarks further, in the same article, that for a flat vane moving normally, as in his *Fig. 55* (which I copy), this

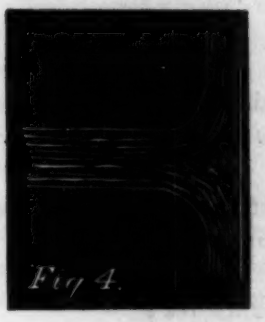


Fig 4.

Fig 5.

direct action is the only action which occurs, but *Fig. 4* (his *Fig. 55*) shows plainly that the direct component of the velocity, $v \cos a$, is *not* changed into the "velocity u of the vane," but the stream is simply deviated, and I fail to see any distinction between the above case, which Rankine calls "direct action," in which the stream is deviated by a cusp of cushion water, and the case shown in *Fig. 5*, in which that cusp is formed of the same material as the rest of the vane.

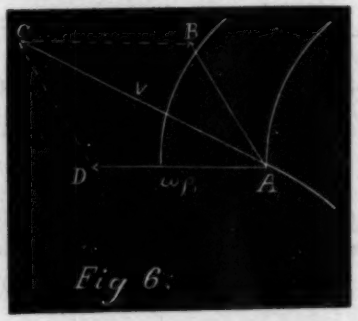


Fig 6.

In *Fig. 6*, let $A\,C$ be the tangent to the guide-plate at its extremity, V the actual velocity of the water on leaving the guide-plate, $\omega\,\rho_1 = A\,D$, the velocity of the initial rim of the wheel, then will $A\,B$ be the velocity of the stream relative to the wheel. Now, if $A\,B$ does not coincide with the tangent to the vane at A, the

stream cannot be suddenly made to coincide with the direction of the vane, or float; neither can we follow Rankine, and assume that the component of $A\,B$ which is normal to the vane is lost. The water, by cushioning, will make its own angles, as roughly shown

Fig 7.

in *Fig. 7*. It is impossible, either practically or theoretically, to determine the new angles, and probably they are not constant; neither is it possible to determine the loss of energy due to eddying; we therefore make the hypothesis that the final direction of the guide-plates, the initial direction of the vanes, the angular velocity of the wheel and the velocity of the flow, are so related

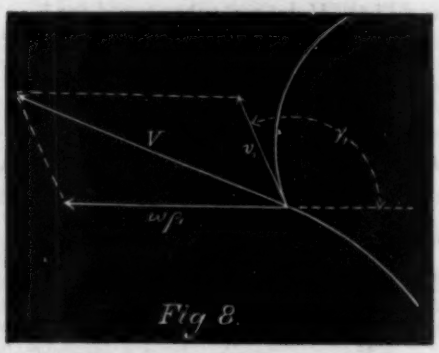


Fig 8.

that the water on leaving the guide-plates shall coincide in direction with the initial elements of the vanes. Any three of the four quantities above mentioned being fixed, the fourth becomes known by this relation. We will leave the angle of the guide-plates to be determined later.

Let V = the actual velocity of the water on leaving the guide-plates;

v_1 = the velocity relative to the vane, as before.

Then V must be the resultant of $\omega\rho_1$ and v_1, and we have *Fig. 8*,

$$V^2 = v_1^2 + \omega^2 \rho_1^2 - 2\, v_1\, \omega\, \rho_1 \cos \gamma_1 \qquad (10)$$

From Bournilli's *Theorem*, we have for the flow of water in the supply chamber, the equation,

$$\frac{p_a}{\delta g} + \mathfrak{h} = \frac{p_1}{\delta g} + \frac{V^2}{2g} \qquad (11)$$

$\mathfrak{h}$ being the mean height of the surface of the water in the reservoir above the wheel. We thus have two equations (10) and (11), introducing one new unknown quantity. Eliminating V in (10) and (11), we have

$$v_1^2 + \omega^2 \rho_1^2 - 2\, v_1\, \omega\, \rho_1 \cos \gamma_1 = 2\, g\, \mathfrak{h} - \frac{2\, p_1}{\delta} + \frac{2\, p_a}{\delta} \qquad (12)$$

Substituting in equation (6) $p_2 = p_a + g\, \delta\, h$, we have

$$\omega^2 \rho_1^2 - \omega^2 \rho_2^2 - \frac{2p_1}{\delta} + \frac{2\, p_a}{\delta} + 2\, g\, h = v_1^2 - v_2^2 \qquad (13)$$

Adding (12) and (13), we have

$$2\, \omega^2 \rho_1^2 - \omega^2 \rho_2^2 = 2\, g\, (\mathfrak{h} - h) + 2\, v_1\, \omega\, \rho_1 \cos \gamma_1 - v_2^2 \qquad (14)$$

From (9) and (14), H being substituted for $\mathfrak{h} - h$, we find

$$v_1 = \frac{a_2 \sin \gamma_2}{a_1 \sin \gamma_1} \left[\omega\, \rho_1 \cos \gamma_1 \frac{a_2 \sin \gamma_2}{a_1 \sin \gamma_1} + \sqrt{\omega^2 \rho_1^2 \cos^2 \gamma_1 \frac{a_2^2 \sin^2 \gamma_2}{a_1^2 \sin^2 \gamma_1} + \omega^2 (\rho_2^2 - 2\, \rho_1^2) + 2\, g\, H} \right] \qquad (15)$$

$$v_2 = \frac{a_1 \sin \gamma_2}{a_2 \sin \gamma_2}\, v_1 = \left[\omega\, \rho_1 \cos \gamma_1 \cdot \frac{a_2 \sin \gamma_2}{a_1 \sin \gamma_1} + \sqrt{\omega^2 \rho_1^2 \cos^2 \gamma_1 \frac{a_2^2 \sin^2 \gamma_2}{a_1^2 \sin^2 \gamma_1} + \omega^2 (\rho_2^2 - 2\, \rho_1^2) + 2\, g\, H} \right] \qquad (15a)$$

$$Q = a_2 \sin \gamma_2\, v_2 = a_2 \sin \gamma_2 \left[\omega\, \rho_1 \cos \gamma_1 \frac{a_2 \sin \gamma_2}{a_1 \sin \gamma_1} + \sqrt{\omega^2 \rho_1^2 \cos^2 \gamma_1 \frac{a_2^2 \sin^2 \gamma_2}{a_1^2 \sin^2 \gamma_1} + \omega^2 (\rho_2^2 - 2\, \rho_1^2) + 2\, g\, H} \right] \qquad (16)$$

The efficiency will be, from equation (8),

$$E = \frac{1}{g\,H}\left\{\omega^2\rho_1^2 - \omega^2\rho_2^2 + \omega\left[\rho_2\cos\gamma_2 - \frac{a_2\sin\gamma_2}{a_1\sin\gamma_1}\,\rho_1\cos\gamma_1\right]\times\right.$$
$$\left[\frac{a_2\sin\gamma_2}{a_1\sin\gamma_1}\,\omega\,\rho_1\cos\gamma_1 + \right.$$
$$\left.\left.\sqrt{\omega^2(\rho_2^2 - 2\rho_1^2) + 2gH + \frac{a_2^2\sin^2\gamma_2}{a_1^2\sin^2\gamma_1}\,\omega^2\rho_1^2\cos^2\gamma_1}\right]\right\} \quad (18)$$

To find the angular velocity that will give a maximum efficiency, make $\frac{dE}{d\omega} = 0$ in (18). For brevity, make

$$m = -\rho_1\cos\gamma_1\,\frac{a_2\sin\gamma_2}{a_1\sin\gamma_1} + \rho_2\cos\gamma_2 \quad (19)$$

$$b = \rho_1\cos\gamma_1\,\frac{a_2\sin\gamma_2}{a_1\sin\gamma_1} \quad (20)$$

$$l^2 = \rho_1^2\cos^2\gamma_1\,\frac{a_2^2\sin^2\gamma_2}{a_1^2\sin^2\gamma_1} + \rho_2^2 - 2\rho_1^2 \quad (21)$$

$$s^2 = \rho_2^2 - \rho_1^2 - m\,\frac{a_2\sin\gamma_2}{a_1\sin\gamma_1}\,\rho_1\cos\gamma_1. \quad (22)$$

Then will $\frac{dE}{d\omega} = 0$, give

$$\omega\,s^2\sqrt{\omega^2 l^2 + 2gH} = m\,\omega^2 l^2 + m\,g\,H; \quad (23)$$

$$\therefore\ \omega^2 = \frac{gH}{l^2}\left[\frac{s^2 - \sqrt{s^4 - m^2 l^2}}{\sqrt{s^4 - m^2 l^2}}\right] \quad (24)$$

and this substituted in (18) will give the maximum efficiency for any turbine, and in (16) will give the quantity of water discharged.

(*To be Continued.*)

ERRORS IN DELICATE WEIGHING.—M. Hennig de Wurtzbourg having noticed some incomprehensible differences in the weights of equivalent quantities, undertook some minute investigations, which showed that balances of precision are often influenced by the electric state of the glass cage which surrounds them. This electricity influences the small auxiliary slides which are placed upon the beam of the balance in order to make it more sensitive. The error resulting from this influence may amount to 600 milligrammes when the cage is strongly charged, and two hours afterwards there may still be an error of ten milligrammes.—*Cosmos, Oct. 5, 1885.*

THE SCHLESINGER SYSTEM OF ELECTRIC TRANSMISSION.

BY W. M. SCHLESINGER, of Bradford, England.

[*A Paper read at the Stated Meeting of the* FRANKLIN INSTITUTE, *held Wednesday, October 20, 1886.*]

Although but a short time has elapsed since the first successful practical application of electricity as motive-power for railroads, nevertheless the number of electric roads now in operation is a comparatively large one. Not counting the roads built in mines, or small ones running on piers, there are at the present time about ten operated in Europe, and the same number in America. Of these, about half the number run only one car, while the others run from two to ten.

The gain of much practical experience is the natural outcome of the operation of these roads, and it is not to be wondered at, therefore, that a great many improvements have been made since Siemens ran his first train in Berlin, in 1879.

Electric railroads may be divided into two large classes. To the first belong all those that derive their current direct from the generators by means of conductors, with which they stand in constant communication, and to the second belong all those operated by means of batteries, primary or secondary. As the road to which I wish to call your attention belongs to the first class, I will only mention of the second class that primary batteries are no longer used for the propulsion of cars, whereas secondary batteries have been employed with success.

The requirements of a road of the first class are generators, motors, stationary conductors along the route, and movable conductors connecting these with the motors.

According to the position of the stationary conductors, the systems of the first class are subdivided into three classes. To the first belong all those that have the conductors on the surface. An insulated central rail generally forms the lead. The uninsulated rails on which the car runs are the return conductors. In some cases, as in Ireland, on the Portrush road, the central rail is dispensed with, the current being transmitted to the motor by

the rails on which the car runs. In this case, the wheels of the car have, of course, to be insulated from each other.

The advantages of these roads are their great simplicity and strong mechanical construction; their defects are that, owing to their unprotected conductors, they are dangerous to persons or animals crossing the track, and therefore better adapted to suburban roads. For the same reason the E. M. F. used with these roads ought not to be larger than 150 volts.

Part of these defects are remedied in the systems of the second class, which comprises all roads carrying the conductors overhead on poles. As it is impossible with these for persons to come in contact with both conductors at the same time, higher E. M. F. can be used, and everyone acquainted with the theory of electric-power transmission knows of what importance it is for the efficiency as well as economy of the plant to use the highest possible E. M. F. The defects of these systems are that they are mechanically not as strong as those of the first class, and that the poles required for them form an obstruction in the streets. Roads of this kind, although they may be suffered in smaller towns having broad streets, would be too great an obstruction to be introduced in the crowded thoroughfares of larger cities.

To the third class belong those roads having the conductors underground in a conduit, access to them being had by means of a slot in the latter. Roads belonging to this class have only recently been built, and but two are in operation at the present moment. These systems combine the advantage of those of the first class, in having ample mechanical strength, with that of the second in being able to use high E. M. F., and in addition to these, they do not form an obstruction to traffic in any way.

Of the two roads belonging to this class, one is located in England and the other here in Philadelphia. This latter road was not built for the purpose of making it permanent or profitable, but simply to demonstrate to the public the practicability of the system. By kind permission of President E. B. Edwards, of the Ridge Avenue Passenger Railway Company, we were allowed to use the track of that company, between their depot and South Laurel Hill, a distance of 2,600 feet, and having a three and one-half per cent. grade near the end at Laurel Hill.

Before giving a description of this road, I will try to show what

is necessary to make a road of this kind successful. The great secret of success in electrical plants of all kinds is, as you all know, good insulation and simplicity of construction. With surface and overhead conductors, good insulation is comparatively easily gained; not so with underground conductors. The slot leading to the conduit gives access not only to the collectors, but also to water, dirt and snow. The first requirement of the conduit, therefore, is to prevent these from coming into contact with the insulation, the second is to allow an easy and quick removal of these foreign substances.

In our present conduit we have tried to attain above requirements by building it in the following manner:

The conduit is 9 inches deep by 3½ inches wide, its bottom is formed of a wooden plate 1 x 3½ inches, and against this the sides of the conduit are pressed and at the same time secured to the cross-ties by spikes. The main sides are wooden beams 4 x 7 inches and 15 feet long, and to this an iron rail forming the top of

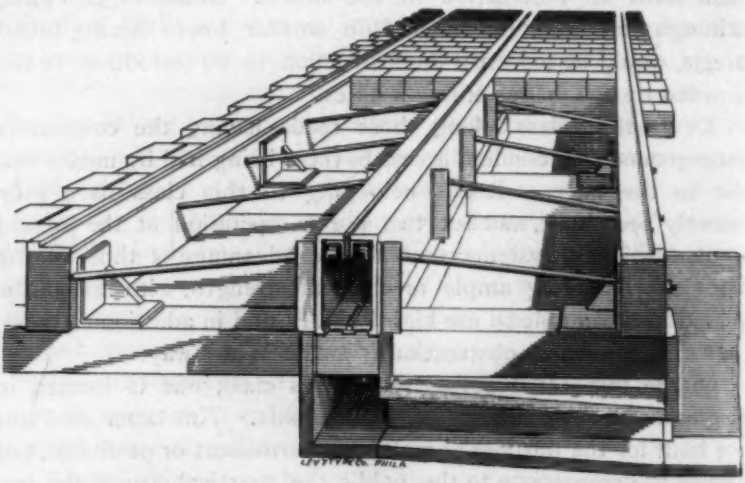


FIG. 1.—Section showing Roadbed and Conduit.

the conduit is secured by a number of bolts. This construction is, of course, not practical for permanent roads. These we have decided to build of strong channel iron 9 inches high and from 15 to 20 feet long. Angle-iron is riveted to the top flange in the manner shown in the accompanying *Fig. 1*. In this it will be seen that one

of its flanges pointing downward parallel to the main side of the channel-iron, forms one side of the slot. In the inverted troughs, formed in this manner, the conductors are fastened so that the contact-sides (*i. e.*, on which the contact-pieces rub), is the lower side. The conductors are much narrower than the troughs, so that contact with the sides is impossible. Any dirt or water entering through the slot will therefore fall to the bottom of the conduit without interfering with the insulation. The conductors are made of copper bars, to the lower side of which channel-iron is fastened. The object of the latter is to protect the copper from being worn away by the rubbing contact-pieces of the collectors and at the same time to keep these latter in their places. The conductors are at each end of the section shorter than the latter and are there replaced by wooden mouldings, the object of which is to protect the insulation from water or dirt getting in between two following sections. These wooden mouldings fill up the whole space, between channel-iron and angle-iron and come within one-half inch of the conductors. The copper of one section is connected to that of the following on our road on Ridge Avenue, by means of well insulated cable soldered to the copper, and passing through holes to the

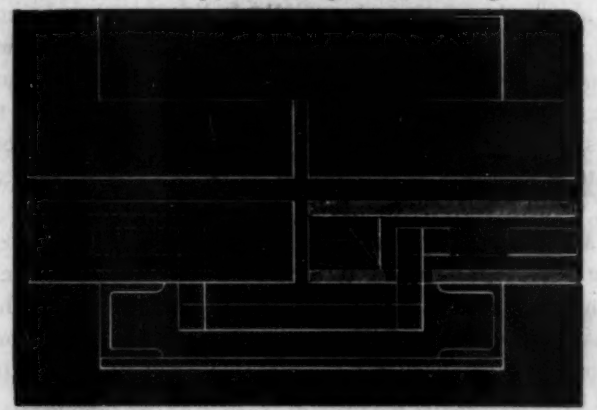


FIG. 2.—Plan showing the Connection between two following Sections.

outside of the conduit where the connection between the cable ends is made. After being well insulated this connection is placed in a recess cut in the wooden beam. This recess is then covered with a plank and filled up with pitch. For the sake of convenience when testing, these connections are at certain intervals

surrounded by large, wooden boxes, with removable lids instead of being placed in the recesses. *Fig. 2*, shows the connection between two following sections of our new conduit. Instead of insulated cables, the connection is made with pieces of copper, protected by an iron box the lid of which is removable. The object of making the connections in such a manner is to allow any section to be tested or cut out of the circuit, by taking the current around it through an insulated cable, without interfering with the conduit or the working of the road. Then again, as all sections are to be made of exactly the same size, it is possible to replace a faulty one in a short time by a new one.

To allow the removal or exchange of the collectors, or the inserting of brushes for cleaning purposes, openings are provided for at proper distances. These are covered by strong cast-iron plates, carrying in place of conductors wooden moulding. The current is taken around these traps, on the outside of the conduit, by means of insulated cable. This is done for the purpose of avoiding an interruption of traffic by the opening of these traps, and to prevent the conductors from being damaged through careless handling.

As above description shows, all appliances are secured to the top of the conduit, leaving a perfectly free space below, nearly seven inches deep. A device for cleaning the conduit can therefore be passed along the bottom, without interfering with the conductors, and the dirt that has fallen through the slot can be swept into pits, from where it is removed by hand. These pits are connected with the sewers to allow the rain-water to pass off. Braces at the sides of the sections keep the slot at the proper size.

The insulation used is red fibre, well soaked in paraffine. Both lead and return conductors, are perfectly insulated, as the slight advantage in cost, gained when using the rails as return conductor, is more than balanced by the greater security from stoppages, caused by faults in the insulation.

The insulation resistance of each conductor was about 12,000 ohms for 500 feet, while laying the road. This would have given 2,300 ohms for each side, the length of the road being 2,600 feet. On the 29th September, the one side showed about 800 ohms. The fall of insulation resistance is due principally to the fact, that the first 500 feet, which have been in the ground now for

three-quarters of a year, were not built with the same care as the rest; then again, the distance between the conductors and side of the conduit was made too small, being only one-eighth inch. Another reason is, that owing to the comparatively few hours we are running every day, it was impossible to keep the caterpillars out of the conduit. These crept up between the conductors and the sides of the conduit and cocooned there. Nevertheless, the resistance between conductors is so large that, with the E. M. F. we are using of about 160 volts, the ammeter does not indicate the slightest leakage. The insulation resistance between conductors is about 880 ohms, and the E. M. F. being 160 volts, the loss through leakage in the conduit is two-elevenths ampères, or twenty-nine watts, or about one–twenty-fifth horse-power. On the 4th September, the whole conduit had been submerged from end to end by means of four fire-plugs, situated along the road. On starting up, the loss was nearly eight ampères, but after the first trip, this was reduced to about three ampères, and, after two hours run, the leaking had stopped entirely. After a very heavy rain, the loss on starting up generally amounts to from one to two ampères, but stops after the first trip.

The main features of the conduit can be summed up as follows: Perfect protection of insulation against dirt or water coming in through the slot, or the spaces between the sections; facilities for cleaning it out; easy access to the connections for the purpose of testing or cutting out a faulty section; facilities for exchanging the latter for a new one, without interfering with the working of the road; easy access to the interior by means of the traps, and perfect drainage.

Perhaps the most difficult part of the whole problem was to devise a good collector, mechanically as well as electrically satisfactory. To give at all times good contact, this latter had to be made independent of the oscillations of the car, and at the same time fastened strong enough to it to enable it to overcome any obstruction in the shape of stones or wedges placed in the slot. The first collector tried rested on four wheels, and was pulled along by the car by means of strong chains. But although this fully accomplished all the electrical requirements, yet it had to be abandoned for practical mechanical reasons. Instead of this, the collector now in use was devised, and this combines good

mechanical, with excellent electrical qualities. It consists, as *Fig. 3* shows, of a cast-iron frame carrying a strong finger reaching into the slot to remove all obstructions. This frame is secured by means of a bolt to the car, in such a manner as to allow it perfectly free motion in a vertical, and sufficient in a horizontal plane. Through a fork in this frame a phosphor-bronze casting passes, fastened to it by means of a bolt, so as to swing freely in a vertical plane and to have enough side-play. This casting passes into the slot, and carries two steel springs well insulated from it and from each other. A strong spiral spring, which takes up all the irregularities in the motion of the car, presses the springs against the conductors. To furthermore insure good contact, the phosphor-

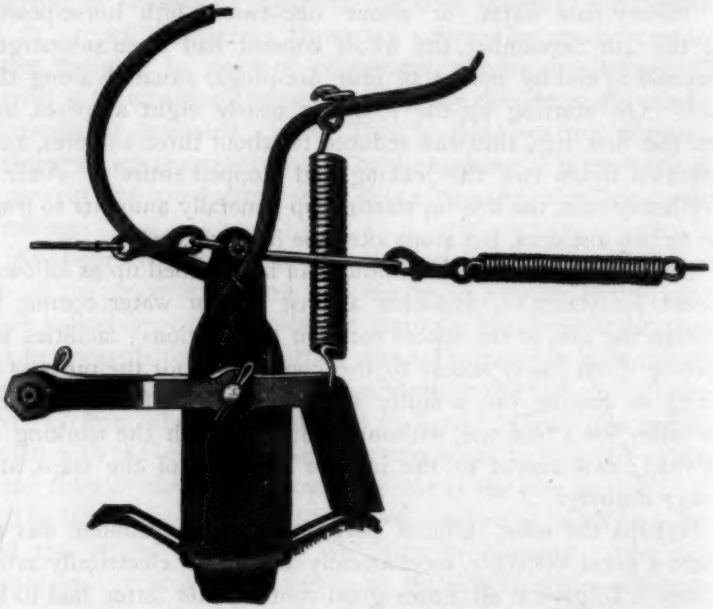


FIG. 3.—The Collector.

bronze casting is connected by springs and wire ropes to a lever on the front platform. With this lever, the casting is tilted in such a manner that in going forward the front parts of the contact-springs, and in going backward the back parts are moved away from the conductors. Two such collectors are supplied to each car, one having the cast-iron finger pointing forwards, the other backwards. The contact between springs and conductors is per-

fect, as the incandescent lamps in the car and the ammeter at the station show. The connection between the contact-springs and the motor on the car is made by means of well-insulated wires, protected where they pass through the slot by steel plates riveted to the phosphor-bronze frame.

Among the advantages that can be claimed for the electric motor over any other motor, small size and weight undoubtedly take a prominent place. Owing to these two properties, it was possible for us to place the motor on the car itself that is intended to carry the passengers, thus doing away with the cost, as well as extra power required by a separate locomotive car. The motor on our car on the Ridge Avenue is fastened to it below the body of the car, between the two axles, and, therefore, does not diminish the seating capacity in the least. The middle of the car was thought to be preferable to any other place, not only because its frame is strongest there, but also because the weight of the motor is equally distributed on both axles. The power is transmitted from the armature shaft to the wheels by chain-gearing. Unless the grades of the road are very steep, it is sufficient to connect one axle only with the motor; with steep grades and heavy loads, it is preferable to transmit the power to both axles, as then the entire weight of the car is effective for tractive power.

To allow easy access to, and good supervision of, the brushes of the electro-motor, the commutator has been placed outside the bearings, the connecting-wires passing through the hollow shaft. The motor in use on our car weighs 1,850 pounds, is built of cast-iron, and can furnish thirteen horse-power. By using the best possible material, like wrought-iron, for the magnets, both weight and size can be very much reduced. The motor designed especially for the purpose weighs about 1,350 pounds, takes up less room, and can furnish seventeen horse-power, or enough power to haul two cars on not too heavy grades. To protect the motor from dirt, dust and water, it is surrounded by a wooden box, having doors at the side, through which the commutator, on the one side, the transmission on the other, can be inspected.

The speed regulation of the car was at first effected by regulating the strength of the field. It is a well-known fact that the work done by a motor within a given time is at its maximum if the counter E. M. F. is half the E. M. F. and sinks, the nearer the

former gets to the latter. On the other hand, the torque is greater the stronger the field, and as the load with which a motor can start up is dependent on this, it is essential to start up with the strongest possible field. When in motion, the required speed is attained by weakening the field and thus the counter E. M. F. Our motor being a shunt machine, it was, of course, necessary to let the main current take several turns round the field-magnets, as, on closing the armature circuit, the low resistance of the latter before revolving would, of course, short-circuit the field-circuit. As far as the motor was concerned, this regulation was very satisfactory, but owing to the fact that one car only was being operated, it was found that the strain on starting was too great for both generator and steam-engine. The regulation was therefore changed to one by means of wire resistance placed under the seats in the car. To allow quick and easy starting up, the field-magnet circuit is always in connection with the conductors in the conduit.

On leaving the conduit through the collectors, the current is taken directly to a regulator-box on the front platform of the car, and in this the connections for the different circuits are made. To allow the cars to be run by unskilled men, like ordinary drivers, the regulation is so arranged that one lever only is required to operate the car. This lever not only allows the car to be started up either forward or backward, but also controls the speed of the same, regulates the light circuit, and controls the electric brake. A diagram, showing the connections in the box, is shown in *Fig. 4*.

The electric brake is composed simply of a large solenoid attached to the car in a horizontal position. The core is made partly of brass and partly of iron and, resting on brass rollers, has a motion of nearly eight inches. It connects by means of a chain with the brake-lever, ordinarily worked by the hand-brake. By putting in or taking out resistance in the solenoid circuit, the pressure executed by it can be regulated at will. The feature of the brake is that it can only be applied when the connections between armature and conduit are interrupted. It is thus impossible to endanger the motor by starting up with the brakes on, or by applying the latter while the motor is propelling the car.

In practice, it will invariably be found that, no matter how good the motor, or what automatic regulation is employed, the practical neutral line will shift from one side to the other of the theoretical

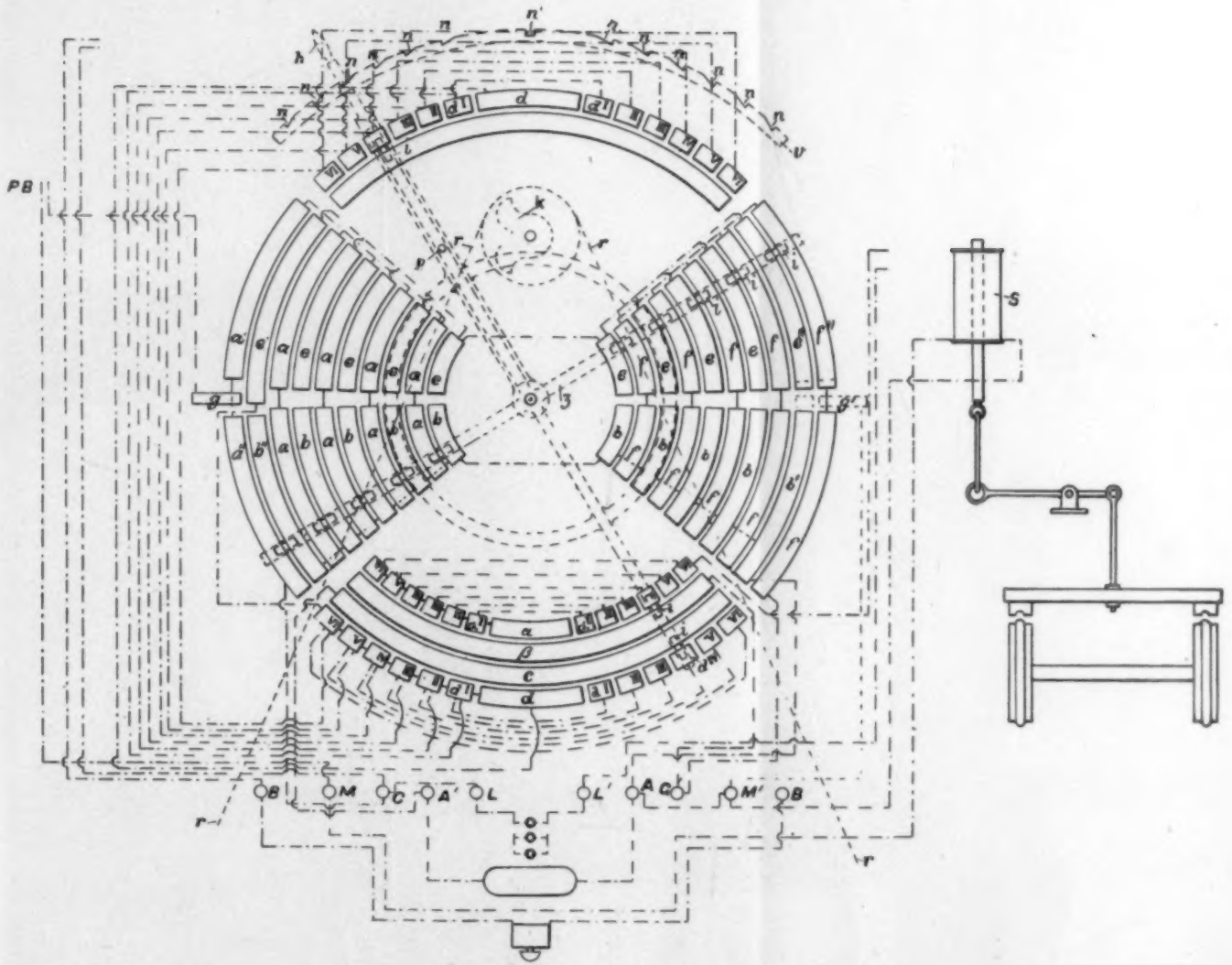


FIG. 4.—Plan showing Connections for Starting, Stopping and Speed Regulating.

neutral line on reversing the motion of the armature. To gain the best results and prevent sparking, it is therefore necessary to provide for means by which the brushes can be shifted to follow the neutral line. To effect this, we have connected the brush-holder by means of wire-ropes to a fork, operated by the lever on the front platform. On moving the lever to either side, the fork is moved a certain distance, thus setting the brushes to one or the other side of the theoretical neutral line. When properly adjusted, the motor runs without a spark at the commutator; the brushes are trimmed every three or four days, the wear they show being mostly due to friction.

To supply the required current, a dynamo is used, which is the exact counterpart of the motor. The armature is of the drum-type, and the winding a modification of the Hefner-Alteneck winding. Owing to the fact that the current taken from the generator is very variable, especially when running one car only, it is impossible to use a series dynamo. On the other hand, it is rather expensive to make a shunt dynamo, giving as high an E. M. F. as 500 or 600 volts. Owing to this and other considerations, we use separately excited field-magnets in our generators and have carried this out on Ridge Avenue, although we there only use an E. M. F. of 160 volts. The exciter used is a small Hochhausen dynamo.

As to the efficiency of the road, it is impossible to give any exact data. The average speed of the car is a little above nine miles per hour; the weight of the car alone is about 5,000 pounds, the weight of the motor and other appliances is 2,100 pounds, giving the total weight of the empty car as 7,100 pounds, or nearly three and one-quarter tons. The capacity of the car is forty-five passengers, which, at 140 pounds per passenger, give an additional weight of 6,300 pounds, a total weight of 13,400 pounds, or about six tons. The current required on the level is between fifteen and seventeen ampères, the E. M. F. being about 160 volts; on the curve on the grade about forty-five ampères are required, the E. M. F. being only 135 volts, owing to the slowing-up of the steam-engine.

NOTE.—Since this was written the connections of the first 500 feet of the conduit have been renewed, and when testing on the 18th of this month the insulation resistance of the one conductor was found to be between 1,500 and 2,000 ohms.

DISCUSSION.

MR. ———.—"How is it proposed to run more than one car?"

MR. SCHLESINGER.—"By using a constant E. M. F. and placing the cars in multiple arc. The resistance of the motor is due to the resistance of its wire, and to the counter E. M. F. Of these, the first is a constant, but the second varies according to the speed of the car. Supposing the motor to have no regulation, its resistance will increase when the speed increases, and decrease when the latter decreases. The result is that with a higher speed, the current passing through the motor, decreases, and, according to the laws governing electric power transmission, the work performed decreases also. Should the speed decrease, the current passing through the motor, and the work performed by the latter will increase. This means that with a given load and a given E. M. F. the motor, if no regulation is used, can only acquire a certain speed, and only a certain amount of current will therefore be able to pass through it, no matter what amount is produced by the generator. It is therefore just as easy to run more than one car, as it is to burn more than one incandescent lamp on the same circuit."

MR. WM. TILGHMAN.—"What is the cost as compared with that of horses?"

MR. SCHLESINGER.—"By taking into account the cost of coal, attendance, maintainance of plant and the interest on capital, the power required per car per day will cost from $2.50 to $3. The power when supplied by horses costs about $6."

MR. W. CURTIS TAYLOR.—"How does it compare with the cable roads?"

MR. SCHLESINGER.—"The cost of the plant required for an electric road is about one-fourth of the cost of that required for a cable road, the efficiency of the power transmission is from two to three times larger, and the wear and tear by far smaller. It will cost much less therefore to operate an electric road than it will to operate a cable road."

MR. W. CURTIS TAYLOR.—"What is the cost of construction per mile?"

MR. SCHLESINGER.—"To change a horse railroad into an electric road with underground conductors, will cost from $20,000 to $25,000 per mile. This includes all the necessary machines.

MYSTERY GOLD.

The (London) *Chemical News*, of May 1, 1885, contains an article on an alloy used in the manufacture of "bogus" gold jewelry. It is stated that the composition of the alloy is:

Silver,	2·48
Platinum,	32·02
Copper (by difference),	65·50
	100·00

The color is described as resembling nine carat gold, and the alloy is said not to be attacked by nitric acid.

A melt of the above-mentioned ingredients in the proportions stated, made for me by the late Mr. Bishop, gave results quite different.

After several meltings, to insure complete admixture, the resulting alloy has a white color resembling zinc, rolls with some difficulty and with a disposition to split or crack on the edges, and is quite readily attacked by nitric acid. C. B.

THE TATHAM DYNAMOMETER.

AN ATTACHMENT DESIGNED TO ELIMINATE ALL JOURNAL FRICTION FROM THE INDICATIONS OF THE SCALE-BEAM.

In using the Tatham dynamometer, to measure the force absorbed by any machine in operation, the method adopted is, first, to couple the shaft of the dynamometer with that of the machine on trial and make the observations of force and velocity; then (without delay) to uncouple and make the same observations, running the dynamometer alone, taking care to run at the same uniform velocity as before. This difference between the two measurements is taken as the power applied to the shaft of the machine on trial.

In each measurement, the scale-beam of the dynamometer tells the difference between the forces exerted by the two parts of the motor-belt upon the pulley.

The first measurement gives the sum of the following resistances:

(1.) The force required to run the machine on trial.

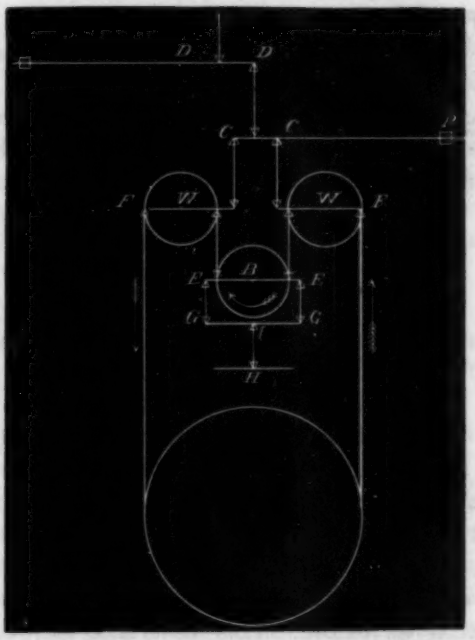
(2) The friction of the dynamometer shaft *B* in its journals.

(3.) The force required to bend and straighten the two parts of the motor-belt.

(4.) The effects of the air-currents and resistances created by high velocities.

The second measurement gives the sum of the second, third and fourth items, and the difference between the two measurements should give the first item, and this must be the case if the circumstances remain constant.

It would, of course, be better if the net power absorbed could be ascertained by one observation, but this is impossible.



As an approximation, however, to this result and for the benefit of tender consciences, I desire to present a sketch of an attachment to the dynamometer, which, I think, would completely eliminate the journal friction of the shaft *B* from the readings of the scale-beam, leaving the items (3) and (4) to be afterwards measured and subtracted as before.

The figure represents a skeleton of the dynamometer. The

journal-boxes which carry the shaft *B* are placed upon a lever-frame *E E* (or side levers), hung from the cradles which carry the pulleys *W W*, by links and knife-edges coincident with the lines of effort of the belt. The frame *E E* is linked by parallel links *E G*, to a parallel lever-frame or side levers *G G*, suspended at the centre knife-edge *I*, from the frame of the machine at *H*.

The force of the journal friction of the shaft *B*, tending to revolve the lever-frame *E E* in the direction of the arrow, will be communicated by the intermediate links and cradles to the scale-beam *C C*, and will deduct itself from the readings of the beam.

W. P. T.

On the new ARTIFICIAL RUBIES.*

By George F. Kunz.

The subject I take the liberty of presenting this evening is of considerable interest at present, both financially and as a notable example of the manner in which the microscope is constantly called into use in almost every profession. Early in the past summer, the "Syndicat des Diamants et des Pierres Précieuses," of Paris, was informed that certain stones that had been sold as rubies from a new locality, were suspected to be of artificial origin. Geneva houses, it was said, had put them upon the market, and it was surmised that they were obtained by the fusion of large numbers of small rubies worth a few dollars a carat into one fine gem worth from $1,000 to $2,500 a carat.

Samples of these artificial stones were kindly procured for me by Messrs. Tiffany & Co.; but I was not permitted to break them for the purpose of analysis, to observe the cleavage, or to have them cut so that I might observe the optical axes more correctly. I should at any time have detected these stones at the first glance with a pocket lens, the whole structure being that of a fused or artificial production. Examination elicited the following facts:

The principal distinguishing characteristic is the presence of large numbers of *spherical bubbles*, rarely pear-shaped, or having stringy portions showing how the bubbles had moved. The ends of these bubbles are always rounded like those present in glass or

* Read before the New York Academy of Sciences, October 4, 1886.

fused mixtures. Viewed *en masse*, the bubbles have a cloudy appearance or are arranged in wavy groups; individually, they seem to be filled with air or gas, and form part of a cloud, the rest having the waviness of a fused mixture. A few appeared to inclose inner bubbles.

In natural rubies, the cavities are always angular or crystalline in outline, and are usually filled with some liquid. Sometimes they are arranged with the lines of growth, forming part of a *feather*, as it is called by the jewellers. Hence the difference between these natural cavities and those caused by fusion is easily marked, even with the pocket lens. I have failed to find in any of these artificial stones even a trace of anything like a crystalline or angular cavity.

Another distinguishing characteristic is, that in many genuine rubies, we find a silky structure (called *silk* by jewellers) which, if examined under a microscope, or under a $\frac{4}{10}$ or $\frac{8}{10}$-inch objective, is found to be a series of cuneiform or acicular crystals, usually iridescent, and arranged parallel with the hexagonal layers of the crystal. When sufficiently numerous, they produce the asteria or star effect, if cut in *cabochon* form with the centre of the hexagonal prism on the top of the cabochon. I have failed to find any trace of these included *cuneiform* or *acicular* crystals in any of the artificial stones, or even any of the marking of the hexagonal crystal that can often be observed when a gem is held in favorable light so that the light strikes obliquely across the hexagonal structure.

Dr. Isaac Lea* has suggested that these acicular crystals are rutile, and my own observation lends strong confirmation to his view. (See paper on "Star Garnets," *New York Academy of Sciences*, May, 1886.) It is my conviction that they were deposited from a solution, either hot or cold, while the corundum was crystallizing, and I doubt whether they will ever be found in any substance formed from fusion. The hardness of these stones I ascertained to be about the same as that of the true ruby, 8·8, or a trifle less than 9, the only difference being that the artificial stones are slightly more brittle. The testing-point used was a Siamese-green sapphire, and the scratch made by it was a little broader but no deeper than that made on the true ruby. As is usually the case with a brittle material, after several trials I faintly

* See *Proceedings of the Philadelphia Academy of Sciences*, February 16, 1869, and May, 1876.

scratched it with chrysoberyl, which will also slightly mark the true ruby.

The specific gravity I found to be 3·93 and 3·95, that of the true ruby varying from 3·98 to 4·01. The difference between the false and true in this respect is, therefore, very small, and is doubtless due to the presence of the included bubbles. As a practical test of genuineness, this method is too delicate for jewellers' use, because, if a true ruby were not perfectly clean, or a few of the bubbles that sometimes settle on gems in taking the specific gravity were not removed, it would appear to have about the same specific gravity as these artificial stones. On examination with the dichroscope, I found that the ordinary image is cardinal-red; the extraordinary, a yellowish salmon-red, like the true ruby of the same color. Under the polariscope, I noted the appearance of what I believe to be annular rings, although I was unable positively to prove their presence, owing to the shape of the stones. Under the spectroscope, the red ruby line is visible, as in the true ruby. The color of all the stones I examined was good, but none was so brilliant as a very fine ruby. The cabochons were all duller than fine true stones, though better than poor ones, and had a remarkable uniformity of color, showing that they were made by one exact process or at one time. The cloudy appearance in all of them is doubtless due in part to the presence of bubbles. The optical properties of these stones are such as to make it evident that they are individuals or parts of individual crystals, and not agglomerations of crystals or groups fused by heating.

The matter was referred by the syndicate to M. Friedel, of the Ecole des Mines, Paris, who was furnished with samples of the stones for analysis. He reported finding the same round or pear-shaped bubbles, and determined the hardness and specific gravity to be about the same as of the true ruby. On analysis, he found them to consist of alumina, with a trace of chromium for the coloring matter. The cleavage was not in all cases distinct. The rough pieces given to him as samples of the stones in their native state had all been worked, so that nothing could be learned of their crystalline condition. When properly cut according to axes, they showed the annular rings. The extinction by parallel light was not always perfect, which he ascribed to the presence of the

bubbles. He states that he himself has formed small red globules with these inclusions by fusing alumina in the oxy-hydrogen flame; and although he has no positive evidence, he believes these stones to be artificially formed by fusion.

On the receipt of M. Friedel's report, the syndicate decided that all cabochon or cut stones of this kind shall be sold as *artificial*, and not precious gems. Unless so marked, all sales of these stones will be considered *fraudulent*, and are punishable under the penal code. It was also determined that all sales so far made, amounting to between 600,000 and 800,000 francs, should be cancelled, and the money and stones returned to their respective owners.

In my opinion, these artificial stones were produced by some process, similar to that described by MM. Fremy and Feil (*Comptes Rendus*, foot-note, 1877, t. lxxxv., p. 1029), by fusing an aluminate of lead with silica in a silicious crucible, the silica uniting with the lead to form a lead glass, and liberating the alumina, which crystallizes out in the form of corundum in hexagonal plates, with a specific gravity of 4·0 to 4·1 and the hardness of the ruby. The color of the ruby is produced by the addition of chromium salt. By this method rubies were formed that, like the true stone, were temporarily decolorized by heating. It is not likely that they were formed by Gaudin's method (*Comptes Rendus*, t. lxix., p. 1342), by exposing amorphous alumina to the flame of the oxy-hydrogen blow-pipe, thus fusing it to a limpid fluid, which, when cooled, is said to have the hardness of the true ruby, but a specific gravity of only 3·45. Nor is it more probable that they were obtained by fusing small natural rubies or pieces of corundum, because by this method the specific gravity is lowered to that of the product of Gaudin. The same holds good of quartz or beryl.

The action taken by the syndicate has fully decided the position that this production will take among gem dealers, and there is little reason to fear that the true ruby will ever lose the place it has occupied for so many centuries. This only shows, however, another of the triumphs of the modern science of chemistry. Although some may be willing to have the easily attainable, there are others who will want, what the true is almost becoming to-day, the unattainable. The one is Nature's gem, and the other that made by man.

ABSTRACTS FROM THE SECRETARY'S REPORT.

[*Presented at the Stated Meeting, September 15, 1886.*]

THE MITIS PROCESS OF PRODUCING WROUGHT-IRON AND STEEL CASTINGS.

At the meeting of the British Iron and Steel Institute, held in May, 1885, Mr. T. Nordenfelt exhibited a remarkable assemblage of specimens of castings made by the direct melting of wrought-iron, which attracted much attention. Great curiosity was manifested in regard to the method by which such results, hitherto impossible of attainment save by the method of forging, were obtained, and which at the time were affirmed to have been produced in Sweden by an entirely new method.

The radical nature of the invention will be understood by all who are familiar with the manipulation of iron and steel, when it is stated that in this process wrought-iron is placed in crucibles, melted, and poured into castings of any desired shape, without in any way changing the quality of the metal. The resulting castings are solid and homogeneous to a high degree; they are considerably stronger than the wrought-iron used in their production; and are flexible and weldable to a degree which it has hitherto been possible to attain only in the highest class of wrought-iron forgings.

In reference to the qualities exhibited by these products, the name "mitis," from the Latin, meaning soft, or mild, has been appropriately chosen.

The process depends upon the addition, to the raw materials employed, of an exceedingly small percentage of another metal, which has the effect of causing an immediate and considerable lowering of the melting-point of wrought-iron employed in the operation. The melting-point of wrought-iron is so high that, even were it possible to obtain in furnaces a heat sufficiently intense to effect its fusion, and with sufficient superheating to permit of casting it in moulds before chilling, the metal is rendered quite worthless by the absorption of the furnace gases, as is demonstrated in the Bessemer process In this operation, the metal at the end of the first blow of the charge is substantially a completely

decarbonized iron, but is utterly worthless for practical uses, principally because of the gases it has absorbed, and which are eliminated in the after-blow by the action of certain admixtures, but with the result of producing a radical change in the nature of the metal, which is no longer wrought-iron, but a mild steel.

Having these difficulties in mind, the inventors of the mitis process, sought for a method of effecting the necessary superheating of wrought-iron without raising the temperature above the melting-point, and, paradoxical as the assertion appears, this is substantially what they have succeeded in doing. In the mitis process, the inventors have taken advantage of the fact, which holds good in many cases, that the alloys of metals melt at a lower temperature than the mean of their constituents. This peculiarity is exhibited in the most pronounced manner by the so-called "fusible metals." These are composed of varying proportions of tin, bismuth and lead, the melting-points of which are respectively at about 440°, 500° and 600° F., while the melting-point of a mixture of equal parts of these metals is at 254° F., or slightly above the temperature of boiling water. The addition of carbon to wrought-iron exercises precisely the effect which is desired, but unfortunately for the purpose in view, the character of the metal is changed, and steel or cast-iron is the resulting product.

To come directly to the point, it was found that the addition of aluminium to wrought-iron produced a very pronounced effect in the desired direction; and, also, that the quantity of aluminium necessary to be added to produce the desired effect is so small that it has no noticeable influence on the desirable qualities of the iron.

Speaking of the method at a recent meeting of the American Institute of Mining Engineers, Mr. Östberg said: "It is of this property of aluminium that we avail ourselves. We heat the wrought-iron just to melting, but not more; and then, as soon as the metal is melted, we add a small quantity of aluminium—from 0·5 to 0·1 of one per cent., thereby producing a sudden lowering of the melting point, and obtaining a superheating of say 300°, 400° or 500° F.—sufficient, at least, for our purpose, to be able to handle the metal in a practical way and pour it into castings." After the accuracy of this interesting observation had been fully verified, experiments were at once undertaken, with the view of ascertaining whether there were other substances besides alumi-

nium that would bring about the same result. These experiments included trials with "every conceivable metal, metalloid and alloy," with the result that nothing else would answer the purpose.

While the essential element of the mitis process resides in the addition to molten wrought-iron of a fractional percentage of aluminium, the successful practical working of the process appears to depend in a great measure upon the manner in which the several details of the operation are conducted. The more important of these, as named by Mr. Östberg, are, the selection of a suitable raw material; the possession of an effective form of furnace for melting the metal without injury; the proper handling of the metal from the time it is ready in the furnace until it is poured into the moulds; and the choice of a suitable moulding material. In respect to all of these details, the inventors claim to have made substantial improvements, which are essential to the successful manufacture of castings from wrought-iron or low-grade steel.

For the melting of the metal, a furnace has been designed in which petroleum, or its residuum, is employed as fuel, and which is described as being remarkably effective, both in respect to the enormous heating effect which it yields, and also in respect to the perfect control of the heats which it permits. These furnaces are so constructed that their operation is continuous. The crucibles (which are worked in pairs), passing gradually from the coolest to the hottest part of the fire, until the charge is completely melted, a freshly-charged pair being introduced as the last pair is removed. From furnaces of this construction operated at the Swedish mitis works, eight to ten pairs of crucibles are drawn per day of twelve hours, the charge being in each case sixty-six pounds of scrap—a record which speaks for itself of the effectiveness of the heating plant.

A special moulding material has been devised, made of hard-burnt finely-ground fire-clay of good quality, and mixed with sugar or molasses as a binding material. This, it is affirmed, is sufficiently refractory to successfully resist, without fusion, the high temperature of the molten metal, and has no injurious effect otherwise on the quality of the castings. The surface of the castings produced is unusually clean, and quite free from embedded sand. The castings require no annealing, as is the case with steel and "malleable" castings, but are simply cleaned up by emery wheels,

or otherwise, and are ready for delivery. To enable the casting to be done with the greatest expedition, water moulds of special design have been devised; the metal is kept at its full heat in the pouring ladle by means of a surface blast of very hot gases, and a number of moulds are fixed around the circumference of a turn-table in such a manner that one mould can be filled after the other, as quickly as it is brought under the lip of the ladle, and the castings are at once taken out of the moulds, so that each mould is ready for refilling as it comes around again under the ladle.

Mr. Nordenfelt, in his paper before the British Iron and Steel Institute, pointed out several facts in connection with the product of the mitis process which are of special importance to constructors—namely, "as the iron runs so exceedingly free without large heads, and as it falls out of the moulds so easily, the method of mitis wrought-iron castings must tend to save labor to a very important extent; and we have already found that it enables us to considerably lighten and greatly vary designs—such as designs of machinery, etc.—as we can, without extra cost, shape our moulds so that we give the strength of the metal where wanted, but only where wanted, whereas in forgings it would often not pay to complicate the shape. This method also enables a constructor to make *much bolder designs*, and of more different forms, knowing that such designs can be easily and cheaply carried out. Here, again, we find great advantage in being able easily to *weld the castings*, as we can cast the parts, which would otherwise be difficult to forge, or which would require much machinery, and weld them on to a bar or rod, as required."

The simplicity of the process above described, the certainty with which it can be operated, the uniformity of the product, and its good qualities in respect to strength and ductility, indicate an extended field of usefulness for it. The most difficult forms have been successfully produced in mitis castings, such as pulleys, smoke-consumers, wheels, knees, bends of piping, etc., having the tensile strength of mild steel forgings, at but slightly greater expense than for castings of ordinary shape; and, it is claimed, that there is scarcely any form of forging which it would not be more advantageous to cast by this method. The mitis castings threaten to seriously incommode the manufacturers of malleable castings, for which they not only offer a perfect sub-

stitute, but one which, in respect to strength and ductility, are distinctly superior; while for many purposes mitis castings can be employed for which malleable castings could not be made. The mitis process has also been applied to the production of steel castings, and with promising results. In one of the methods experimentally tested, the steel castings were from wrought-iron scrap as raw material, with the addition of the proper proportion of cast-iron to bring the percentage of carbon to the point required for each special purpose. To enter into the details of the various qualities of the products obtainable by the mitis process, by varying the character of the raw materials, would unnecessarily lengthen my remarks, the purpose of which is simply to describe its general features and the wide range of its applicability as a substitute for processes at present in vogue. (W.)

GERMANIUM, A NEW ELEMENT.

The *Berichte* of the German Chemical Society lately contained a brief statement of the discovery of a new element, by C. Winckler, the following details of which will be interesting:

Weisbach lately found in the Himmelsfürst mine, near Freiberg, a mineral which he named argyrodite, and which, on analysis, yielded seventy-three to seventy-five per cent. of silver, seventeen to eighteen per cent. of sulphur, 0·2 per cent. of mercury, but the analysis always showed a deficiency of six or seven per cent. Winckler has discovered that this deficiency is due to the presence of a new element, for which he proposes the name *Germanium* (symbol, Ge). The new element closely resembles antimony, and in acid solutions gives a white sulphide, soluble in ammonium sulphide. When argyrodite is heated in a stream of hydrogen, it yields a black, crystalline sublimate, which melts to brownish-red drops. This is principally germanium sulphide, mixed with mercury sulphide. It dissolves in ammonium sulphide, and is re-precipitated by hydrochloric acid as a white powder, readily soluble in ammonia. When heated in a current of air, or with nitric acid, the sulphide yields a white oxide, which is not volatile at a red heat. This oxide is soluble in potash. The oxide and sulphide can both be reduced by heating in a current of hydrogen, and yield the element as a gray, moderately lustrous substance, which is only volatile (without previous fusion) at a full red heat, and

therefore much less so than antimony. The volatilized element is deposited on cooling in small crystals much resembling those of iodine. When germanium, or its sulphide, is heated in a current of chlorine, the easily volatile white chloride is formed, soluble in water.

Winckler considers germanium as the element indicated by the periodic law as probably existing between antimony and bismuth He is now engaged in determining its atomic weight. (W).

BOOK NOTICES.

SOME FEATURES OF THE RECENT EARTHQUAKE.

The above caption appears at the head of an article, by Mr. McGee, in *Science*, of September 24th. He begins by describing the "coastal plain" about Charleston, which is thirty or forty feet in altitude and diversified by "broad, irregularly meandering and inosculating troughs;" the higher parts being "naturally forested." It is a "slightly accented" topography. The geologic structure is remarkably simple (or will be when the formations are thoroughly studied); though the superficial stratum is "obscurely stratified." Beneath this member a stratum "contains sulphurets and various salts, either free or quickly liberated on oxidation." This phrase is not clear. If the stratum and its contents were oxidized, it would no longer contain sulphurets, and if anything were oxidized in such a stratum, it would be the sulphur in the sulphurets. Its precise thickness is not known, owing to depressions in the "subjacent surface" and from the impossibility of separating it from the "superjacent member." No satisfactory explanation is given of how a part could be at the same time "surface" and "subjacent." The "superjacent" sands are sometimes replaced by an "estuarine alluvium." The phosphate beds are "underlain by petrographically similar cretaceous deposits, increasing in heterogeneity somewhat downward to 2,000 feet," but some reasons favor the supposition that a "considerable thickness of cretaceous strata are infraposed." Of the phenomena it is said "the effects of the earthquake are themselves no more conspicuous than the indications of inequality and intensity" of the disturbance. Amongst the observations are mentioned "simultaneity of detonations with tremors."

The predominant effects of the shock of August 31st, are: "*first*, fissuring of the surface of the earth; and, *second*, crushing of foundations and chimneys, together with, *third*, slight displacement in different directions (and sometimes torsional) of buildings." The italics are Mr. McGee's own, but they do not quite give this thought lucidity. Further on we are told that "the architecture of Summerville is characteristic," but we are soon relieved of the necessity of puzzling over this singular fact and seeking to account for it by the hypothesis of a prehistoric settlement by buccaneers on reading a description of a most commonplace method of building which one may observe anywhere in the

South. Mr. McGee safely concludes that the sound of the detonations came "directly from the earth," but adds (as if this were too daring a statement to pass unqualified) "either as sonorous vibrations, or as soundless pulsations of such a period as to be converted into sound-waves on passing from earth to air." Ten Mile Hill, half-way between Charleston and Summerville, developed "craterlets" and "crateriform" orifices. "These crateriform orifices are now surrounded by their solid ejecta in annuli attenuating peripherally." It is likely that Mr. McGee means to say by this ornate sentence, that there are rings of dirt around the holes through which the water spouted. The water, we are told, was "extravasated," which suggests the "black eye" that industry received; and he records with some astonishment that it smells still of "sulphuretted hydrogen," although the quake is so long past. In all cases of "personally observed and well-authenticated compressive distortion, the kinks occurred in the low grounds." (He is speaking of railway rails.) Of the monuments in the cemeteries, "many have suffered torsional displacement, but of these some have turned with others against the sun; while others are displaced laterally without overthrow." He leaves the reader to picture this state of things, if the reader can. A picture of a "Charleston chimney twisted with the sun" is referred to. His conclusion is that "inferences as to the azimuth of the wave-paths in Charleston are premature."

We should think, from a perusal of his article, that they were! Nevertheless, "there are large areas within which the intensity of the disturbance culminated." This would seem to imply that in other areas the intensity of the disturbance was going on just as usual. Also, "within these areas," first referred to, there "are foci or nodes of maximum vibration, circumscribed and separated by annuli in which the vibration was less severe." Whatever may be the light which Mr. McGee claims to have shed on this very interesting and distressing phenomenon (and we do not see that it can be much), we may certainly credit him with adding to the English language more words than have been contributed by all American authors put together. His style, too, is really and truly his own. William M. Evarts might envy his sesquipedalian words, were they strung together so as to present a picture to the mind: but in this latter particular, it must be confessed that Mr. McGee is not in danger of being confounded with the eminent New Yorker. In this connection, it may be recalled that on the day after the earthquake the country was informed, through the Associated Press correspondent at Washington, of some marvellously clever observations made by Mr. McGee at Washington while the tremor was going on. It seemed a wonderful instance of presence of mind and fertility of resource, that on the occasion of an unexpected earthquake—(for it has nowhere been suggested that Mr. McGee was aware that an earthquake was about to come off)—a whole half column of "seismographic observations" should have been made. A tumbler of water (we were told) acted as an admirable seismograph to indicate the direction from which the waves came; while the "amplitude of the oscillation was readily ascertained by the swinging of the six-foot head-board of a bed." To one not so full of imagination as Mr. McGee, the history of that night would have probably been told in this simple statement—"I was in bed read-

ing when the earthquake came, and, noticing that the head-board of the bed rocked considerably, I jumped up, and observed even the water in the tumbler on my night-table quivering."

The results of his observations in and around Charleston are similarly simple when extracted from the ponderous verbosity in which they are enclosed. Thus: (1.) The geology of Charleston is clear when you know it. (2.) The shaking upset and twisted large objects all over the region from Charleston to Summerville. (3.) Holes were formed out of which water, mud, etc., were thrown. The odor of rotten eggs was noticed and is noticed still in places. (4.) It looks as if the motion at Summerville was more vertical and that at Charleston more horizontal, but it is doubtful if I would have thought of this if Prof. Milne had not mentioned it as characteristic of the central regions of disturbance of the Japanese earthquakes which he in a commission of the British Association has been studying for some years. (5.) Neither I nor anyone whom I have been able to find knows much about either the cause or the more detailed history of the convulsion. This statement is what one extracts from the report after reading eight columns of *Science*, with the necessary general philologic preparation to penetrate the lavish paint of thought and word. Do you ask why one should not furnish the public with this simpler pabulum, which would be so much more easily digested and take so much less time to swallow? What would become of the Government printers if one did not call the "tide marshes" of South Carolina "inosculating troughs?" And how would that pleasing industry to the rural Congressman, the shipment of "pub. docs.," be maintained? But this kind of thing degrades science, and teaches the uneducated public to look upon the scientific bureaux as word-mongering establishments.

THE WATCH AND CLOCKMAKERS' HANDBOOK, DICTIONARY AND GUIDE. By F. J. Britten. Sixth Edition. London: W. Kent & Co., Paternoster Row. New York: E. & F. N. Spon, 35 Murray Street. 1886.

We had occasion to speak of the excellency of this work in this JOURNAL when its fifth edition was presented. How well the encomiums of this work then expressed were deserved, is shown by the short time in which a sixth edition is called for. Nor is this new edition a mere reprint of its predecessor. It has, on the contrary, valuable additions in text and illustrations, that bring it up to quite recent date in the science and arts connected with horology. So, for example, we find an illustrated description of the single three-legged gravity escapement of Dr. Leonard Waldo, published but a few months since in the *Horological Journal*. In his "Notes to the Sixth Edition," the author says: "In obedience to the request of several correspondents, who desired to use this work as a guide in setting out the escapements most generally used, I have added drawings where needed for the purpose. Other suggestions have also been met by the introduction of new matter, an index, and separate alphabetical lists of the French and German equivalents. Much of the book has been rewritten to bring it up to date, while descriptions of many useful tools and devices of recent inventions

are here published for the first time." This, we think, refers very modestly to the many valuable additions and changes this useful book has received in its new edition, which required an enlargement of seventy-two pages.

L. H. S.

REPORTS OF THE COMMITTEE ON INDEXING CHEMICAL LITERATURE. Dr. H. Carrington Bolton, Reporter. From the *Proceedings of the American Association for the Advancement of Science*, Vol. XXXIV. Ann Arbor Meeting, August, 1885. Read before the Chemical Section A. A. A. S. August, 1886.

These reports, which cover a little less than twelve pages, have the impress of care, as do all of Prof. Bolton's communications. It will be seen that of the myriads of chemical compounds now known, and of the many which are in hand, only four are published, viz.: petroleum, iridium, uranium, melting and boiling points. Four are reported as in progress, viz.: carbon monoxide, by Prof. W. R. Nichols, since deceased, explosives, meteorites and common salt. Nine are projected, viz.: specific gravity tables, chemical synonyms, milk analysis, a continuation of petroleum, chemical patents, aluminium, gems, scientific bibliographies and copper. Prof. Bolton appends an instructive little note on the needs of abbreviations and the defects of the various methods employed in recording scientific journals.

Prof. Bolton prints in the *Transactions New York Academy of Science* an interesting lecture experiment, showing the properties of potassium and sodium peroxides to a class by dropping the respective metals into their melted nitrates. He warns intending amateur experimenters against trying the same reaction in melting potassium chlorate without previously providing themselves with insurances on their lives and houses.

AMERICAN JOURNAL OF MATHEMATICS.

The lectures now being delivered at Oxford by Professor Sylvester on his "New Theory of Reciprocants," will appear in the coming numbers of the *American Journal of Mathematics*.

The lectures are presented in quite simple style, and will be exceedingly interesting to all students of the modern algebra, or, more accurately, of the theory of invariants. The first eight or nine lectures will appear in the forthcoming number of the *Journal*, Vol. VIII, No. 3.

ANHYDROUS CHROMIC ACID.—M. H. Moissan gives a simple method for purifying chromic acid from sulphuric acid, and states the action of anhydrous acid upon several simple bodies. Oxygen and ozone are not affected. If a mixture of chromic acid and sulphur in excess is heated, they combine with a very brilliant light, forming a brilliant lecture experiment. As soon as phosphorus and chromic acid meet, under proper conditions of heat, there is an explosion and ineandescence. On heating a mixture of dry chromic acid and arsenic, there is a combination with brilliant light. Chromic acid when melted and maintained at a temperature of about 200° violently attacks the metals which are easily oxidized. With sodium there is an explosion with great heat and light.—*Ann. de Chim. et de Phys., Aug., 1885.*

PROGRAMME OF LECTURES FOR THE SEASON 1886–87.

The following Lectures will be delivered during the coming winter, viz.:

1886.

Nov. 15, PROF. PERSIFOR FRAZER, D. Sc., FRANKLIN INSTITUTE, "Elements of Chemistry."

" 19, MR. E. A. GIESELER, C. E., Superintendent of Construction, Fourth Light-house District, "The Illumination of Maritime Coasts."

" 22, PROF. FRAZER, "Elements of Chemistry."

" 26, MR. J. LUTHER RINGWALT, Editor of the *Railway World*, "From the Trail to the T-Rail."

" 29, PROF. FRAZER, "Elements of Chemistry."

Dec. 3, MR. RINGWALT, "From the Travail to the Train."

" 6, PROF. FRAZER, "Elements of Chemistry."

" 10, MR. F. LYNWOOD GARRISON, F. G. S., Philadelphia, "The Microscopic Structure of Iron and Steel."

" 13, DR. N. A. RANDOLPH, Biological Department, University of Pennsylvania; Editor of the *Medical News*, "Life and Death."

" 17, PROF. CLEVELAND ABBE, Army Signal Office, Washington, D. C., "Popular Errors in Meteorology."

" 20, DR. RANDOLPH, "Thought and Sleep."

1887.

Jan. 3, MR. C. HANFORD HENDERSON, Instructor in the Manual Training School, Philadelphia, "The Bessemer Steel Process and its Modifications."

" 7, MR. EDWARD ATKINSON, Boston, Mass., "The Growth of Manufactures in the U. S. considered as a Social Problem."

" 10, MR. HENDERSON, "Glass-Making."

" 14, PROF. CHAS. F. HIMES, PH.D., Dickinson College, Carlisle, Pa., "The Stereoscope and its Applications."

" 17, MISS HELEN C. DES. ABBOTT, Philadelphia, "Plant Chemistry as an Applied Science."

" 21, MR. WILFRED LEWIS, M. E., with Wm. Sellers & Co., Philadelphia, (Subject to be announced).

" 24, MISS ABBOTT, "The Chemical Basis of Plant Forms."

" 28, MR. JOHN HARTMAN, of Taws & Hartman, Philadelphia, "The Crucible of the Blast Furnace."

" 31, PROF. FRANCES EMILY WHITE, M. D., Women's Medical College, Philadelphia, "Hygiene."

Feb. 4, MR. JOHN BIRKINBINE, Philadelphia, "Rainfall and Water Supply."

" 7, PROF. J. BURKITT WEBB, Stevens Institute of Technology, Hoboken, N. J., "Mechanical Paradoxes."

Feb. 11, MR. CARL HERING, Electrical Engineer, Philadelphia, "Electricity: The Different Forms in which it Manifests Itself."

" 14, PROF. WHITE, "Hygiene."

" 18, MR. HERING, "The Electrical Transmission of Energy."

" 21, MR. WM. F. DURFEE, M. E., United States Mitis Company, New York, "Hero of Alexandria and the Arts and Mechanism of his Times."

" 25, PROF. L. D'AURIA, U. S. Hydrographer, Philadelphia, "Some Peculiarities of Tidal Rivers, with Especial Reference to the Delaware River."

" 28, MR. C. O. MAILLOUX, Electrical Engineer, Brooklyn, N. Y., "The Storage of Electrical Energy."

Mar. 4, MR. BIRKINBINE, "Iron Smelting in the United States."

" 7, COMMANDER J. R. BARTLETT, Chief of the Hydrographic Bureau, U. S. N., Washington, D. C., "The Physical Geography of the Sea."

" 11, CAPT. OTHO ERNEST MICHAELIS, U. S. A., Watervliet Arsenal, W. Troy, N. Y., "The Army of Kukuanaland."

Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, October 20, 1886.*]

HALL OF THE INSTITUTE, October 20, 1886.

Vice-President CHAS. BULLOCK, in the Chair.

Present, 152 members and sixteen visitors.

Additions to membership since the previous meeting, four.

The Secretary reported the following recommendations from the Committee on Science and the Arts, viz.:

The *Elliot Cresson Medal* to Mr. HUGO BILGRAM, of Philadelphia, for his "Bevel-Gear Cutter;" and to the PRATT & WHITNEY COMPANY, of Hartford, Conn., for their "System of Interchangeable Gears."

The *John Scott Legacy Premium and Medal* to PHILIP J. GRAU, of Philadelphia, for his "Improvement in Feed-Water Purifiers;" CYPRIEN CHABOT, of Philadelphia, for his "Method of Forming Bevelled Rims on Watch-Cases;" and HUGO BILGRAM, of Philadelphia, for his "Bevel-Gear Cutter."

The above-named recommendations were severally approved, and the Secretary was directed to take the usual measures in the premises.

The Special Committee on Reorganization reported the following resolutions, with a recommendation that they be adopted, viz.:

"*Resolved*, That the chairman be authorized to increase the number of the committee, at his discretion.

"*Resolved*, That the committee be authorized to solicit subscriptions for the purpose of purchasing a site, and for the erection of new buildings suitable for the enlarged work of the INSTITUTE.

"*Resolved*, That when *bona-fide* subscriptions, amounting to $100,000,

shall have been obtained, the committee shall be authorized to contract for a suitable piece of real estate."

The resolutions were unanimously adopted. The Secretary presented the following:

At a conference of the officers of the United States Signal Office and the Committee on Meteorology of the FRANKLIN INSTITUTE, held Tuesday, October 19th, to consider the feasibility of establishing a State Weather Service, the following was unanimously adopted:

Whereas, The FRANKLIN INSTITUTE ceased the direction and management of meteorological observations in the State of Pennsylvania, because of the establishment of a National Weather Bureau, and

Whereas, It is believed that the time has arrived when the INSTITUTE may largely aid the people of this state and the United States Signal Service in disseminating their forecasts and weather statistics, collect climatic and other data that will be of much importance to our agricultural, manufacturing and commercial interests; therefore, it is resolved by this meeting, to recommend to the INSTITUTE the passage of the following resolution:

"*Resolved*, That the subject of organizing a State Weather Service be referred to a special committee, to be appointed by the President, with the request to report a plan for the same to the stated meeting in November."

The resolution was adopted.

The Secretary reported the receeipt of a communication from Mr. P. B. DELANY, of New York, and at present in Berlin, in reply to the protest of Mr. PAUL LACOUR, of Copenhagen, referred to in the proceedings of the September meeting.

On motion of Professor Houston, a special committee was appointed to inquire into the respective merits of the claims of Messrs. LaCour and Delany, with instructions to report as early as possible. The Chairman appointed Mr. E. Alex. Scott, Prof. E. J. Houston, Mr. W. W. Griscom, Mr. Alex. E. Outerbridge, Jr., and Dr. Wm. H. Wahl, to constitute the committee.

Mr. W. M. SCHLESINGER, of Bradford, Eng., then read a paper on "The Schlesinger System of Electric Transmission," with an account of the trials of the same, on the line of the Ridge Avenue Passenger Railway Company. The paper, with discussion thereon, appears in the November impression of the JOURNAL.

Mr. WM. F. DURFEE, of New York, by special invitation, gave an interesting description of the process of making "mitis" castings of wrought-iron and steel. Mr. Durfee illustrated the subject by means of a diagram of the melting furnace employed, and by the exhibition of a number of characteristic specimens.

The Secretary's Report embraced an account of certain evidences of earthquake action near Haddonfield, N. J.; a description of the Castner process of producing the metals of the alkalis; a statement of the comparative production of iron and steel in Great Britain and the United States in the first half of 1886; and the exhibition of interesting specimens of composite photography, made by Mr. W. Curtis Taylor, and of isochromatic photography, by Mr. Fred. E. Ives.

The meeting was then adjourned. WM. H. WAHL, *Secretary*.

THE "NOVELTIES" EXHIBITION OF THE FRANKLIN INSTITUTE, 1885.

ABSTRACTS OF REPORTS OF THE JUDGES.

(*Continued from page 320.*)

GROUP II*g*.—STEAM-HEATING AND VENTILATION.

Judges:—William Vollmer, *Chm.;* C. S. Schwenk, C. E., M. D., M. R. Mucklé, Jr., F. B. Paist, S. M. Vauclain, Coleman Sellers, Jr.

E. C. TAINTER, PHILADELPHIA.

The Cooper Steam Generator.—Has a boiler for furnishing hot-water or low-pressure steam, and is applicable for heating dwellings or green-houses with steam or hot water for various laundry, dairy, farm and other operations requiring steam or hot water, and even for driving light machiney.

The fire-pot or furnace is in the form of an inverted frustrum of a cone, terminating in a large smoke-flue: around this fire-pot is an outer shell, which is of similar form. The space between these two cones forms the water-space, and a curved top bolted to the outer shell forms the steam-space of the boiler.

The charging-door is in the smoke-stack or flue, and a separate internal passage leads the coal to the centre of the fire-pot. The lower part of this internal coal-chute or "self-feeder" is surrounded by a coil of pipe, having a top and bottom connections with the water-space. This coil affords additional heating-surface, assists in promoting circulation, and, as it never becomes red hot, it is said to prevent the coal in the "feeder" from being burned before it reaches the fire-surface. The principal parts of the generator are cast-iron, and it can be readily taken apart if desired.

Two joints are packed with copper-wire, and it is claimed that if a leak should occur, it is readily stopped by caulking this wire.

A self-feeding supply-valve, operated by a float, admits water as needed, and a glass water-gauge, a steam-gauge and a safety-valve are also provided. The self-feeder is said to hold coal enough for ten or twelve hours. When used for steam-heating, the generator is provided with an automatic damper-regulator to control the draught.

If water cannot be obtained under sufficient pressure to feed the boiler, a barrel or cast-iron tank, set sufficiently high up, will answer the purpose.

The makers claim for the generator: moderate first cost, no brick-work or foundation, absolute safety, ease of operation, reliability and great heating capacity.

For cheapness, efficiency and ease of operation—

(*A Silver Medal.*)

JAMES SHORE, PHILADELPHIA.

The Germantown Open-Grate and Hot-Water Apparatus.—Combinations of hot-air and steam-heating and hot-air and hot-water heating devices are common, many being in use at the present time. Mr. Patton's apparatus combines the advantages of an open fire-grate, with a hot-water heating system for the rest of the house, in which it is placed. In appearance, it is like the ordinary open-grate, with the sides and back of the fire-place serving as one of the walls of a water-chamber, similar to the water-back in the range, and arranged in such a manner as to absorb the greatest amount of heat from the fire. Radiators or pipe-coils can be placed in rooms on the same floor where the grate is stationed, or on the floor above. The radiators or coils of pipes are connected to top and bottom of the water-chamber, surrounding the grate, and the whole system filled with water, will heat the rooms in which the radiators or coils are placed, the water as it cools returns to the bottom and is replaced by hot water from the top of the water-chamber. A reservoir, placed at the highest point of the system serves to keep the pipes, radiators and water-chambers full of water, and free from air, as is usual in all hot-water heating plants. In addition to the advantages of heating a house with an open-grate and hot-water, the inventor claims that a thorough system of ventilation can be obtained in connection with this apparatus, in the following manner:

The pipes leading from the water-chambers are carried through the smoke-flue of the grate to the highest point where heat is required. The outlets and returns from these pipes to the radiators or coils enter the rooms close to the floor, an opening of an inch or two is left around the pipes coming through the wall, which serves as a means of drawing the heavy air, which falls to

the floor, from the room and into the smoke-flue. This is replaced by fresh air from the windows and doors.

The room in which it is placed is thoroughly ventilated at the fire-place.

To induce additional circulation in the room in which the grate is placed, and to make use of the heat given off by the cast-iron frame, a small flue is cast on each side of the fire-place, adjoining the water-chamber and part of the main casting.

These flues extend to the top and front of the frame, and have openings provided with registers close to the floor.

In the grate exhibited, no provision has been made for removing the scale and sediment, which may accumulate in the water-chamber, and which at times makes inoperative the ordinary range water-back.

For novelty and efficient combination of open-grate with hot-water heating system— (*A Bronze Medal.*)

BROGAN & SMITH, PHILADELPHIA.

Heating Apparatus.—A combined hot-air and water apparatus for heating buildings, especially those which are too large to be easily warmed by one furnace.

This apparatus consists of a cast-iron base, supporting a conical furnace, over which a short vertical flue boiler, covered by a wrought-iron smoke-box, which is connected with two or more sheet-iron drums.

The products of combustion pass through the boiler, heating the water, and thence to the chimney. The whole device is enclosed by a galvanized-iron case, which forms a hot-air chamber, and gives the apparatus the general appearance of an ordinary portable-heater.

The boiler is tapped for pipes, by which the hot-air is carried to the radiators, situated under the more distant flues, and the rooms above are thus heated by indirect radiation.

The hot-air from the air-chamber is conducted in the usual manner to the more adjacent flues. A cast-iron tank, with float-valve and gauge-glass, indicates the height of water in the boiler, supplies the water necessary to keep the system always full, and allows for expansion.

The furnace is provided with a shaking-grate and dumping arrangement, worked conveniently from the outside.

The apparatus is commendable as an ingenious combination of two well-known systems of heating, and for its thorough utilization of the heat of the fire.

A. PENROSE BENNER, PHILADELPHIA.

Philadelphia Manifold House-Heater—Is so arranged that the air may be heated by one furnace for each room of a building, and conveyed thereto by separate pipes leading from the furnace.

The furnace is provided with the necessary ash-pit, doors, dust- and smoke-flues and other appurtenances ordinarily found in furnaces for this purpose, and the whole is inclosed in brick-work.

The heaters are made of wrought-iron, not thinner than fourteen gauge, and are closely riveted at the joints to prevent leakage of coal-gas into the heater.

They are suspended within the brick-work by irons riveted to the heaters and built in the brick-work, respectively, and are arranged in a convenient manner, whereby to make the best disposition of the space and to admit of a free circulation of heat and the products of combustion from the furnaces around and among them.

The smoke passes from the furnace to the stack at the upper part of the brick-work, except when the fire is first started, when a damper may be opened into the dust-flue to increase the draught.

Arranged around the fire-box is a common cold-air receptacle, which forms part of the fire-box. Fresh air is admitted to the receptacle through flues.

The base of each wrought-iron heater is connected by a neck to this receptacle. A vapor-pan is placed at each side of the fire-box for moistening the air.

The upper portion of each heater is connected with a tight hot-air distributing flue, which leads to the apartment to be heated. The operation of the apparatus is as follows: The fresh air enters the receptacle through the flues, and passes through the separate heaters, which are exposed to the fire, and thence escapes through the separate distributing pipes into the several apartments to be heated. Thus each apartment is heated independently, and a room on a high floor cannot rob one on a lower floor of any portion of the heat intended for it.

In the apparatus exhibited, instead of carrying heated air by separate pipes to individual rooms, each heater of the system, at

its upper part, connects with a general air-space, situated under the roof of brick-work enclosing the furnace.

This space or reservoir of hot-air is tapped, as may be desired, with pipes, conducted to the several apartments to be heated.

THOS. H. HOLMES, PHILADELPHIA.

Newton's Steam-Trap.—An objectionable feature of this trap, in our opinion, is the hinged cock, or connection from steam-pipe, which is liable to be a source of trouble.

We recognize the efficiency of the trap at the expense of considerable steam, and the mechanism is liable to get out of order.

(*Honorable Mention.*)

A. J. KOCH, PHILADELPHIA.

Barry's Steam-Trap.—This trap, although not meeting the Judges' views as to what a thoroughly reliable and economical steam-trap should be, has, we think, several points of marked excellence.

By the ingenious device employed, the water is effectually removed, and at the device the same time precludes any waste of steam. For novelty and simplicity of action—

(*A Bronze Medal.*)

THE PHILADELPHIA EXHAUST VENTILATING COMPANY, PHILADELPHIA.

Blackman Exhaust-Wheel or Blower.—The following distinctive merits are claimed for this device, *i. e.*, it exhausts or blows a large amount of air with a given power, than any other air-moving machine, because of the peripheral flange or end buckets peculiar to this wheel. Has a large feed-area, and will give a larger amount of pressure than any other fan.

Will run in any given position, without a change in bearings or supporting-frame.

In *drying*, its superiority is unquestionable, and its value as a ventilator is apparent.

For general excellence— (*A Silver Medal.*)

J. HENRY MITCHELL, PHILADELPHIA.

Smith & Caldwell Ventilating-Fan.—This has a regulator for